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Designing Tools for Reflection:
A Concept-Driven Approach

By

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Declaration

I hereby declare that, the contents and organization of this dissertation constitute my own original work and does not compromise in any way the rights of third parties, including those relating to the security of personal data.

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Abstract

We are surrounded by objects. We often use and interact with them to do our daily activities. They do not only support us and augment our abilities, but also, can be considered as companions of our thoughts. We think with objects, because they contain information about us: about our memories, experiences, emotions, and activities as *Sherry Turkle* highlights (2011). Furthermore, our everyday objects are increasingly computed, smart and connected to the Internet. They are able to collect data, elaborate and provide real-time feedbacks. These feedbacks cannot only support us to improve our activities, but also enables critical thinking and reflection on our actions. This resonates very well with what *Donald Schön* meant by having reflective conversation with materials at hand (1983; 1996). He highlighted that materials –artifacts– of a situation talk back to designer, so they enable and support reflection in action of designing. So, how about if we consider that our daily objects can talk back and make us think on our actions in order to consider alternatives? This dissertation, is an attempt to consider this opportunity.

The nature of this dissertation is mostly conceptual and its scope is defining the physical and behavioral characteristics of smart artifacts able to provoke thoughts and reflection in user leading to a conscious behavior change. I sought to use existing theories about reflective thinking in HCI and beyond, as valuable sources for developing design concept. I have been inspired by the Concept-Driven interaction design research (Stolterman and Wiberg 2011) and created and defined the whole structure of this dissertation based on this methodology, from the definition of the concept – *Tool for Reflection* – to the construction of a theoretical model from the design outcome –*Make Me Think* model. During this process, I used different methods such as conducting literature analysis, context analysis, survey, participatory session and prototyping.

The sustainable urban mobility behaviors in the city of Turin (Italy) as the target behavior and home as the place for using *Tool for Reflection* have been chosen for this research. In particular, informed by architectural studies, I conceptualized *In-Between Places* as a category of places that connect home places to city places. I suggested to consider such areas as suitable places for evoking thoughts on urban mobility behaviors, in home.

This dissertation provides a theoretical perspective with which to guide the design of smart objects that evoke reflection. It first provides a set of characteristics of a *Tool for Reflection* as a physical artifact. Then it provides a theoretical model, considering the relationship between a *Tool for Reflection* and a user. The key contributions include the design of the *Sóle*, a smart lamp, not only

as an example of a *Tool for Reflection* with its theoretically pre-defined characteristics, but also as an instrument for iterating from design to the theory. The overall approach, the methodology and the findings should be of interest in particular to researchers working on design for reflection in the HCI. More broadly this dissertation can be of interest of researchers in the HCI, whose research is around designing artifacts, both as an 'outcome' and as an 'instrument' of the research process.

Maliheh Ghajargar,
January 2018.

Contents

Paper 1:

Ghajargar M., Gargiulo E., Giannantonio R. (2015). *Mobile Awareness: design for connectedness*. In proceedings of MobileHCI'15, pp. 1038-1041. ACM.

Paper 2:

Ghajargar M., Mangano G., De Marco A., Giannantonio R. (2017). Design Thinking applied on data storage innovation: a case study. *The Design Journal*, 2(sup1), pp. 3776-3788. Taylor and Francis.

Paper 3:

Ghajargar M. (2016). *Designing connected artifacts for domestic environment: Reflections on the design processes and methodologies.* In proceedings of national forum of PhD students in Design, pp. 95-103.

Paper 4:

Ghajargar M., Wiberg M., (2018). Thinking With Interactive Artifacts: Reflection as a Concept for Design Outcomes. *Design Issues.* 34(2), 48-63. MIT press.

Paper 5:

Ghajargar M., De Marco A., Montagna F. (2017). *Wise Things: when smart objects stimulate reflection,* In proceeding of 11th IHCI conference, pp. 233-238. IADIS press.

Paper 6:

Ghajargar M., Wiberg M. (forthcoming- 2018). *Designing Things and Places for reflection, a design agenda for social IoT*. In Social Internet of Things (Eds.) Soro A., Bereton M., Roe P. Springer.

Paper 7:

Ghajargar M., (2017). Toward intelligent environments: Supporting reflection with smart objects in the home. *interactions*, 24(4): 60-62. ACM.

Paper 8:

Ghajargar M., Wiberg M., Stolterman E. (forthcoming- 2018). Designing IoT Systems that Support Reflection: A Relational Approach. *International Journal of Design.*

List of figures:

List of tables:

Chapter 1

Why: *Designing Tools for Reflection*

1.1 Background

The interest in designing computing and smart artifacts to support reflection, especially in the context of everyday lives is growing. In the HCI (Human-Computer Interaction) community, "reflection" often refers to the action of thinking about the information provided by computing artifacts, in order to capture awareness about the actions and experiences and also its consequences (Sas and Dix 2009; Baumer et. al. 2014). The topic of reflection has been investigated from both a theoretical and a practical perspective in the HCI. From a theoretical perspective, for instance Fleck and Fitzpatrick provide a framework summarizing the literature outside of HCI about reflection. They include in their framework three important aspects of reflection, namely the purpose, the condition and the levels of reflection and then they include technologies that can support reflection (Fleck 2012; Fleck and Fitzpatrick, 2010). In a more specific way Baumer et. al. see reflection as an alternative to traditional and persuasive ways of behavior change, especially for sustainable behaviors (2014). Focus on the materiality of interaction with physical smart objects and how it can influence human behaviors and evoke reflection have also been the subject of study in HCI and design (Ghajargar & Wiberg 2018; Ghajargar, De Marco & Montagna, 2017; Wiberg 2018).

From a digital-practical perspective, for instance Kalnikaite and Whittaker (2011) developed *MemoryLane*, a digital memory application that helps people to organize their mementos according to the place, people and objects. From physical-practical perspective, the *Data Souvenirs* of Aipperspach et. al. (2010) inspires by environmental psychology emphasizes on the important role of the physicality and familiarity of objects that support reflection. Social interactions also seem having a relevant role in reflection process, because they create the environment for dialogue and talk with other people about experiences and this helps to recall memories. For example, interactive systems for behavior change, increasingly, focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action (Plodderer, et. al. 2014).

1.2 Motivation

If the purpose for designing smart objects and services is to help and support people to change their behaviors, so why do not use persuasive technology (e.g. Fogg 2003) or other strategies which are well established for that purpose? Why choose reflection as a tool for that purpose?

A number of factors can motivate researches in using objects to evoke reflection and so to encourage sustainable behaviors in user: 1) the challenges with persuasive technologies and strategies for behavior change, in particular for sustainable behaviors; 2) sustainable behaviors require ecological awareness, which requires reflective thinking on actions and behaviors that impact environment negatively and ; 3) physicality and materiality of smart and computing objects that can evoke thoughts and shape human behaviors (Figure 1).

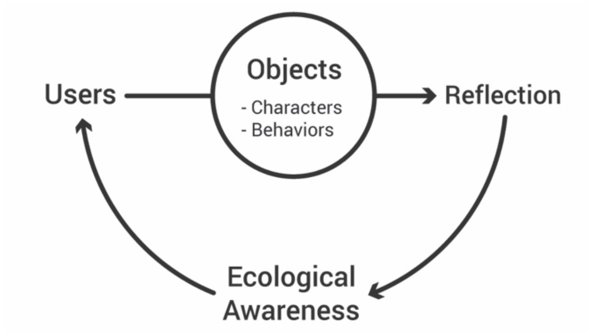

Figure 1: Motivations.

Challenges with Behavior Change Design

Persuasive Technology is a branch of research that employs the use of computers and digital technologies as instruments in order to change, shape, support or stimulate human behaviors. The Persuasive Technology or Captology are terms coined by B. J. Fogg in 1996. The Captology –acronym: Computers As Persuasive Technologies– is the study of computers as persuasive technologies. This includes the design, research, and analysis of interactive computing products (e.g. mobile phones, smart objects, websites and video games etc.) created for the purpose of changing people’s attitudes or behaviors.

The persuasive technology is based on the motivation and ability of people to change. While this can be useful for changing, or influencing simple behaviors and bad habits – e.g.

smoking – it might prove some difficulties regarding bigger and more complex changes, those that are mostly conceptual and related to our ways of thinking. Brynjarsdóttir et. al affirm that while persuasive technology methods seem making easier the support of sustainability, they might lead to patterns of breakdown in longer terms. This is mostly because, persuasion is based on a limited framing of sustainability, human behaviour and their interrelations (Brynjarsdóttir et. al 2012). Sustainability in general is a broad and complex context. So, in order to tackle the issues related to sustainable and inclusive behaviors, we need a major change in our way of thinking and the way we approach such issues. This issue has been investigated in a number of researches. For instance, according to the studies conducted by Schultz et. al (2002), people who consider themselves as a part of the natural environment will show more inclusive and sustainable behaviors. In their model, they suggest that attitudes about environmental and societal issues are rooted in the degree to which people believe that they are part of the natural environment. These findings also distinguish between egoistic concerns, which focus on self, and biospheric concerns, that focus on all living things (Schultz et al 2002). Schultz et. al demonstrate the associations between these implicit connections with nature – it exists outside of people's conscious awareness – and the explicit environmental concerns (2004; 2007).

Therefore, there are two major concerns regarding current behavior change design systems that mostly follow persuasive techniques, especially in the area of sustainability. The first one, as I described above is related to the inefficiency of such methods especially in area of sustainability. Other challenge with design of persuasion-based behavior change systems that have been expressed already in literature concerned about ethical issues regarding such systems. In particular, a major attention has been paid to avoid the design of systems that patronize people and dictate behavior (e.g. Miller 2013; Tengland 2012; He, et. al., 2010).

Ecology, Reflective Thinking, Materials

The word of *ecology* rooted in Greek *oikos* that means "home" or "place to live". It deals with interactions and relations of natural and artificial things with each other and also with their surroundings.[1] These interactions and interrelations are all about the exchanges of material, energy and information, which keep the system or *oikos* working.

Ecological awareness on the other hand is about being aware of human's relationships with natural and social environments, which consequently lead to changes in attitudes and behaviors. Ecological awareness is an attitude and mindset and it goes beyond of doing something because every-body does, or because it is socially acceptable, and/or because it has to be done for an immediate and perceptible result and functional goal. For instance, Wilson's *Biophili*a (1984) concerns about human's innate bond and connections with natural environment. So, the actions and behaviors, which have negative impact on the natural environment are the result of having disregarded or neglected such bond and

[1] www.merriam-webster.com/dictionary/ecology

connections. *Garreth Hardins*'s three lows of human ecology invite us to think in a different way (1992):

> First Law: "We can never do merely one thing."
>
> Second Law: "There's no away to throw to."
>
> Third Law: The impact (I) of any group or nation on the environment is represented qualitatively by the relation: I = PAT (P: the size of the population; A: per-capita affluence, consumption; T: the damage done by the technologies that are used in supplying the resources.)

So, the ecological awareness is actually the ability to reflect upon our relationships with natural and artificial environments. When It comes to the ways of thinking, attitude and our approaches that help us to change behaviors, the reflective thinking or reflection has been highlighted by many researches.

Donald Schön is one of the best-known scholars who touched upon this topic in design field (e.g. Schön 1992; 1983). In particular, he considers the materials of a design situation as instruments that guide and help designers to reflect and review the decisions. He outlines that this reflective conversation with materials of a design situation helps to improve the artifact as the outcome of a design process (1992). I have been always wondering how we can use this knowledge as a concept for design outcomes and products. For instance, how an everyday use artifact can talk back to us about something important to reflect about, through its materiality and physicality and what are the key characteristics of such artifact?

Some behavior change design approaches have already focused on the aiding role of the designed artifacts. Those approaches concern about the characteristics of the artifacts –the forms, feedbacks, materials, graphics, etc.– that can change the ways people use such artifacts and consequently change their behavior. For instance, Donald Norman (e.g. 1988, 2013) has introduced the concept of affordance in design, which was originally coined by psychologist J. J. Gibson (1977;1979). Gibson defines this concept as the actionable properties between the world and an actor, which is about the relationships between them. Further, Donald Norman introduced the perceived affordance, which highlights that designer cares about what user perceives more than what actually exists (Norman 1988, 2013). Lockton's in Design with Intent (2009) provides a method and tools for designers working in the area of behavior change. In this method, he introduces the architectural lens, which is about using features of products and built environment to influence and change behaviors. The theory of affordance and the example provided above, confirm that materials and artifacts can shape our behaviors, so our thinking.

In the following section, I will briefly present some examples of using smart objects to evoke reflection with the purpose of behavior change.

1.3 Smart objects and reflection

Considering smart objects as companion of thoughts and reflective thinking a number of projects have investigated the role of physical artifacts in achieving such purpose. For instance, *Keymoment* (Laschke et al. 2015) is a key hook with the purpose of fostering more healthy and sustainable urban mobility behavior, by encouraging its users to take their bike key instead of their car key. In particular, the design of the key hook helps users to remember and reflect on the choice of transportation in a pleasant way, at the moment of leaving home. A similar idea of using a key hook as an artifact for reflection on urban mobility behavior has been conceptualized by Ghajargar et. al (2015), which has inspired by environmental psychology and the theory of our implicit connection with nature (Schultz et al 2004). Mckinnon's *Domestic Reflections, Electric Reflections* (2016) which focuses on the everyday mundanity and critical design as an approach for designing interactive and every-day objects for sustainable behavior change. The Eco-Feedback Technology is another concept, that uses digital and physical artifacts, mostly ambient displays in order to capture awareness about user behaviors (Froehlich, Fidlater and Landay, 2010). Feng Gao's *Design for Reflection on Health Behavior Change* (2012), takes an instance on alternative ways to persuasion-based systems for behavior change specially in dietary context. *Reveal-it* is another example of using large digital displays for empowering people, by evoking thoughts on energy consumption at both individual and collective levels (Valkanova et al. 2013).

Social interactions also seem to play a relevant role in the reflection process, because they require talking with other people about the experiences, so helping to recall memories. For example, interactive systems for behavior change increasingly focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action (Ploderer et al. 2014). Reno and Poole's *It Matters If My Friends Stop Smoking* also focuses on the role of social support for reflection and behavior change, especially on the role of people with whom user has a close relationship (Reno and Poole, 2016).

Research questions

My research has been focused on one big and general research question: **how to design physical, computing and smart objects in order to evoke reflective thinking in user?**

I addressed this general research question by answering three interrelated subordinate research questions:

- Research Question 1: How are reflective thinking, behaviors and objects interrelated?
- Research Question 2: What are the characteristics of a *Tool for Reflection*? – i.e. physical and interactional –

- Research Question 3: Which place in home is suitable for *reflection on* an urban activity? – i.e. urban mobility behaviors –

1.4 Contributions

Although the whole process of my research – both the theoretical and methodological parts – has been aimed towards designing a concrete and physical interactive artifact for supporting reflection, I believe this dissertation has more to offer. During this journey, I designed and prototyped an interactive artifact, but also sought to develop theoretical models and methodological tools and frameworks that were useful for the design process. I believe my PhD project, would contribute mostly to the design community of HCI (Human-Computer Interaction), and I believe it does it in three different ways: 1) Methodological; 2) Theoretical and 3) Practical.

Methodological *contributions*

I went through the process of designing –concept development and prototyping– informed by theories. I used theories in different manners according to the design process requirements (Beck and Stolterman 2016). For instance, I used theories as *shaping tools* to develop the design concept and then used them as *analytical tools* to validate the design concept.

The overall methodology of my research, contributes to the HCI and design communities. I used theories for designing, and the outcome of the design process contributes to theories. In addition, the methodology I used to define a set of concrete characteristics of *tools for reflection* cannot only contribute to the research community of design for reflection, but it also can be replicated and used in other areas of HCI researches whereas an artifact should be designed either for the research purposes (e.g. Zimmerman, Forlizzi and Evenson 2007), or for everyday use. Through this dissertation, I sought to contribute theoretically and methodologically to the *concept-driven approach* (Stolterman and Wiberg 2010). The methodological contribution, specifically is related to the design process of this approach. As an attempt, I translated the most traditional design activities such as problem setting and the problem solving into the practice of *concept-driven approach* in order to argue about how concepts become designs in this approach. Problem Setting is a process through which the problems are understood, framed and constructed from the materials of the problematic situation (Schön 1983, pp. 39-40). Then, problems become 'given' in problem solving process. As I will describe in more detail in chapter 3 and 4, the problem setting process, in this dissertation is translated into the "Concept Defining" process, and the problem-solving process into the "Concept Situating" process (e.g. Dorst 2004; 2011, Cross

Further, the way I used participatory design workshop is another practical contribution to the community. I developed a method that help to choose an everyday object in a meaningful way to become an IoT device/smart object. This seems to be relevant because, it helped designers and researchers in HCI to be more thoughtful, regarding what they are designing, and how they choose what to design.

Theoretical *contributions*

I explored literature, in order to understand if reflective thinking, can have such an effect to change people's behavior. In addition, I explored already existing body of knowledge to answer my second research question about the role of the materiality of objects to that purpose. I present the result of this extensive literature analysis in forms of theoretical models and also as guidelines for designing artifacts for reflection. I provided a set of characteristics, as the requirements of such artifacts.

In addition, inspired by Taylor's after interaction (2015) and Wiberg's materiality of interaction (2018), I suggested a relational approach to study and design IoT devices. In this approach, a particular attention is paid to the relationships and not interactions. I explored different relationships that users can establish with a computing and smart artifact. Building upon those models I drew the "*Make Me Think*" relationship, which can be used by designers to design such artifacts.

Practical *contributions*

The prototype of an interactive lamp –*Sóle*– and the whole process of designing and prototyping it, make most of the practical contribution of my dissertation. I would like just to highlight that this prototype is not –never has been– something apart and divided from the rest of my research nor the more important part of my dissertation. Instead it has been blended and interwoven in the whole process, it is just an example of probing my thoughts in a real world and see it working. In addition, I designed and developed a generative tool that has been used and tested during the participatory session, which can be another practical contribution.

1.5 Thesis outline

In chapter 2, I will describe my research methodology, which is inspired by concept-driven approach to interaction design research (Stolterman and Wiberg 2010). I will briefly explain the methodological steps of my research and I will reflect on the process by bringing into discussion three ways of reasoning: inductive, deductive and abductive reasoning. In chapter 3, I will describe the first step of my research, which is "Concept Defining". I will go through the whole process of the literature study method, citing also the relevant literature. Then I define the concept *Tool for Reflection*. Further I validate the concept by using FBS (Function, Behavior, Structure) framework. In chapter 4, I describe the "Concept Situating", where I will explain what is the target behavior and which place in the home environment is the place for reflection on that behavior. I will also explain how I defined them through the questionnaire and also participatory session.

In chapter 5, I will describe the “Concept Appropriating”, whereas the whole process of designing and prototyping will be provided. The chapter 6, is about the last methodological step of my research, “Constructing Theories”. In this chapter I will describe how I used the prototype in order to make theories. In chapter 7, I will reflect on the whole process of my research and will discuss on three points in designing for reflection: 1) giving form to *Tools for Reflection,* 2) considering reflection as a reference task, 3) designing with theories and constructing theories from designed artifact. In chapter 8, I will draw conclusions and will discuss on further points for future researches (Figure 2).

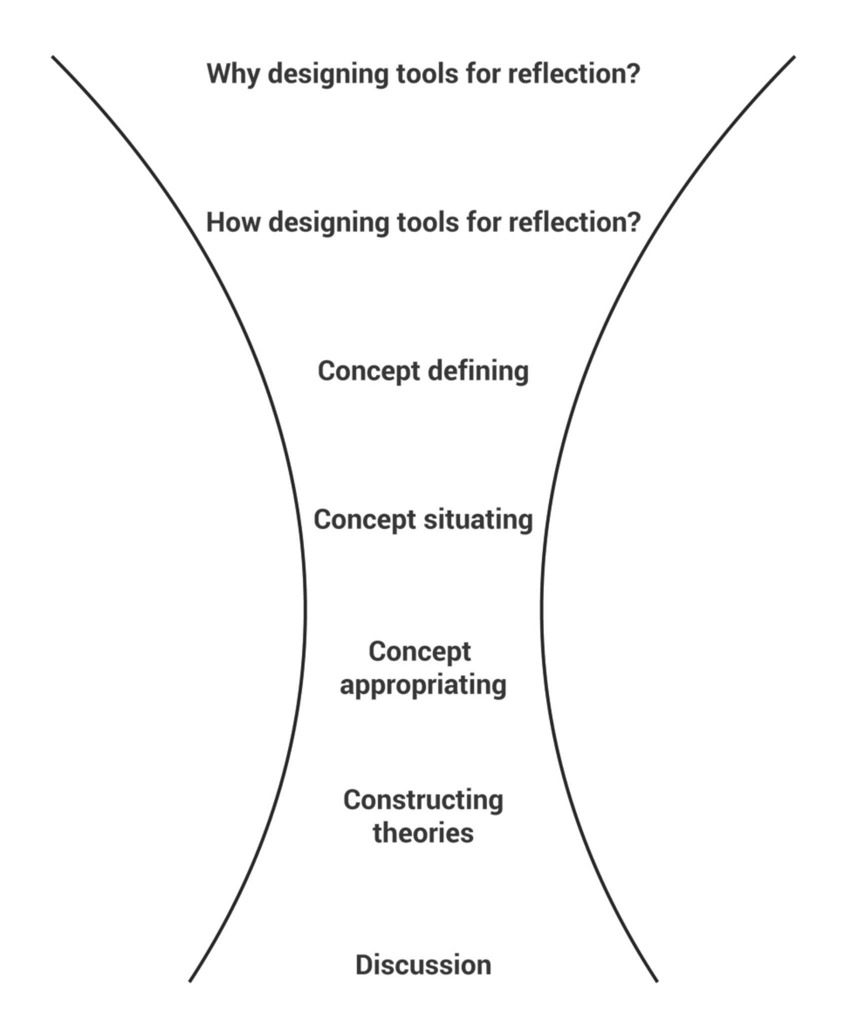

Figure 2: The thesis structure.

Chapter 2

How: *Designing Tools for Reflection*

The nature of this research is conceptual, both theoretically and designerly. Its intention is *to explore new territories and design spaces*, by going beyond of just designing, rather being inspired by theories for designing. Therefore, the methodology behind it has been influenced mostly by the *concept-driven approach* (Stolterman and Wiberg, 2010). So, first, I am going to briefly describe the key points and principles of the *concept-driven approach*. Then I will explain the ways it has been useful and appropriate for my research. After going briefly through some epistemological notes on this methodology, I will describe the actual steps of this research. Thereafter, I will draw and discuss on some points that can be added to it for its further developments.

2.1 Concept-driven approach

This approach is likely about designing concepts that are *theoretically* and *historically* well-grounded and it is an alternative to other situation-based approaches in HCI design – traditional HCI design research methods, such as *proof-of-concept,* or empirical studies based methods such as *user-centered design* or *participatory design*.

As Stolterman and Wiberg (2010, pp. 98) explain, in this approach:

1. The point of departure is conceptual and/or theoretical rather than empirical.
2. The research furthers conceptual and theoretical explorations through hands-on design and development of artifacts.
3. The end result –that is, the final design– is optimized in relation to a specific idea, concept, or theory rather than to a specific problem, user, or a particular use context.

Furthermore, they define some principles of concept-driven approach, for instance a concept-design should probe directly a desired theoretical idea. Thus, it should go directly from a pure theoretical idea to a concrete artifact. Consequently, the artifact functions as a tool to argue the theory behind it. A pure theoretical idea turns to a concrete artifact, by being interpreted and probed into the world, so it becomes the carrier of knowledge. Then the artifact can be used and also improved according to the original theoretical idea and concept. Stolterman and Wiberg (2010) stated that the final design can be optimized *"in relation to a specific idea, concept, or theory rather than to a specific problem, user, or a particular use context"*: and it does not mean that there is no user or use context for the artifact, rather the artifact after being implemented can be improved according to the conceptual idea or the theory. It implies the iteration circle between the artifact and the theoretical idea, whereas one can improve the other. The quality of the concrete artifact, which is a matter of concern in this approach–details, colors, texture, forms, behaviors, etc.–unlike usual approach in HCI towards prototyping, helps further this iteration, as the artifacts as a real and usable product (e.g. Carrol and Kellogg 1989).

Concepts

Generally, in Industrial Design, concepts can emerge from variety of sources. For example, from user studies, field studies, from collective idea generation techniques –e.g. brainstorming methods– or more individual, abstract and philosophical ideas. Literature, language and arts are also often good sources for concept generation. Concepts are generally "words" or "short phrases" that can describe a big picture of the artifact properties; concepts convey also the purpose or the overall intention of designer. Then those concepts can be developed further through a realization that are the best fit of a design situation, the available resources –time, skills and materials. Therefore, the concept and its realization depend heavily to the designer/design team and its feasibility studies. In addition, in creativity studies, the Concept Generation has been considered as a convergent process (Cross 2000; 2011). It starts with a fuzzy point of generating a variety of ideas from limited knowledge and resources available and then synthesizing and focusing in order to make a decision (Jones 1970; 1991; Gero 1996). Making decisions and choosing one concept over others, occur usually according to many different situational factors such as production process, functionality, feasibility, time, skills, designer fixation and etc. (Evans 2008, Goldschmidt 2016)

Theories. Concepts. Artifacts.

Theories, concepts and artifacts are three axes of my research project. I used theories to create concepts, used concepts to create an artifact and I used artifact for constructing theories. Being inspired by scientific theoretical models is not a common way for generating concepts in design practice. This is because, 1) designers mistakenly believe that theories limit the creative flows, which should be kept as open as possible. Therefore, in order to avoid any obstacles that might block the free creative flow, theoretical models are always skipped; 2) designers are often in shortage of time for creating concepts, and so they can not properly do analytical work prior to concept generation. Worth noting that scientific theories have been always used in more advanced design steps, from mechanical design of the components, ergonomics, the material choices, interactions and down to the aesthetical details. The scientific theories have always helped designers with providing guidelines and principles in order to have a functional and usable final result, during the process and also testing the final result. In other words, we can say that scientific theories are entangled with design activities, but they are not used during early stages of design, for instance for generating concepts.

In my PhD research, I was particularly interested to generate concepts from theories and literature in HCI, mostly because of three reasons: 1) theoretical models in HCI are usually a condensed and synthesized form of empirical studies, field studies and user studies. So, they have already human-centered components; 2) I believe concepts are already in literature and the designer's job is to find them and to appropriate them to a particular situation and for a particular purpose. This might be done also by using the same tools that designers usually use for generating concepts; 3) time: I had one year time to generate a concept, which looks like a big opportunity comparing with the amount of time practitioner designers might have. Therefore, the *concept-driven approach* definitely is the appropriate and useful approach for my PhD research.

In *concept-driven approach*, Stolterman and Wiberg state, that *concept* become generated directly form theories and are the overall organizing principle of design: are the *whole* (2010, pp 104). The whole or the designer's intention is perceptible and visible for the concept designer and not necessarily visible for whoever else interact with the artifact. The *character* of the artifact itself also as the final result of *concept-driven* design, plays also an important role. The attention to details, context, meaningfulness and the overall quality of design, makes the outcome of this process as something carefully crafted, rather than just being an instrument for testing functionalities. As Janlert and Stolterman (1996) define, the *character* of the artifact as *whole*, as the over-all expression of the artifact, so this is like seeing whole from user's eyes, or who may interact with the artifact. Herein the artifact's *character* –as the final result of an interaction design research– is carefully designed, then it can be used as a tool for theory construction.

Accordingly, the methodological process of this dissertation, has involved three main steps: 1) the first was the accurate study in literature, theories and history of the subject of my research in order to be prepared for the next step and creating a concept; 2) then generating a theoretical concept, which was actually the result of an extensive literature study; 3) other activities and using tools such as questionnaire, participatory session, interviews and context analysis served to nourish and sustain the concept; 4) designing and making an artifact based on the design concept and insights received from previous steps; 5) presenting illustrative and constructive models and making the theory.

Between one step and another there was always an iteration in order to re-consider and revise the research question.

In summary, the methodology of this research seeks to discuss and contribute to the concept-driven approach to interaction design research, by arguing around four matters in design: 1) concepts; 2) artifacts; 3) people; 4) theories.

How do "concepts" matter?

In concept-driven approach, a design concept is often referred to an idea created between two different kinds of iterations 1) empirical and theoretical studies and 2) prototyping and testing artifacts with users. On the basis of the insights received from these two cycle of iterations, then a concept is usually defined. The main contribution/outcome of this approach is the concept-driven "knowledge", rather that concept-driven "artifact", by considering concepts as carriers of knowledge and also the ways that an artifact can embody knowledge.

In my research, concept has been generated through two levels of higher and lower abstraction. I call the first level ""Concept Defining"" which is the answer to the "why" question of design. It conveys meaning, intention and motivation of the design. The second level I call it ""Concept Appropriating"" which is the answer to the question "what" in design process. And direct the design process towards a well-defined purpose, aim and outcome.

How do "artifacts" matter?

In this approach, the artifact as the outcome of design process, is designed both for the purpose of everyday use and for research. So, it blends the two well-known approaches to design: the traditional one, that focuses on the user needs and use context, paying attention to forms, compositions, materials and cultural context and the Research Through Design approach (Zimmerman, Forlizzi and Evenson 2007), which focus on the research purpose and uses the designed artifact as a tool in research process.

Artifacts, both as prototypes or research tools and as final design objects with more attention paid to details of aesthetical, cultural and emotional properties, serve as carriers of knowledge. It means they are the realization of theoretical ideas, they can be used as a product by end users and also as tools to iterate from tangible demonstration of ideas and concepts to theories. Artifacts matter in this approach, as they are able to reduce the level of abstraction in theoretical concepts, by trying to realize them and see them out there in the world. In this way concepts become real (Figure 3).

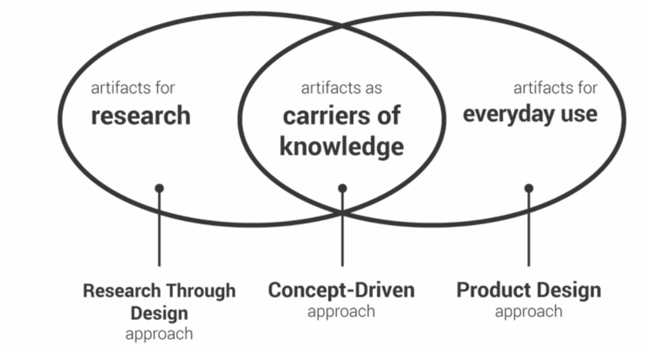

Figure 3: The role of artifacts in different approaches.

How do "people" matter?

People are always the matter of concern in design process. Usually a user-centered design process, starts with a brief. It contains often the context of the design, analysis of the user studies data in order to define a user need/desire. It shows that user have already been involved in the study and the scope is to find a solution to a user's need. In short, user-centered designing is always the activity of ideation and making artifacts with the purpose of addressing a user need or desire.

Since the rise of user-centered design approach especially in HCI, the understanding of user's needs and the way they interact with a computing artifact has been a central concern.

How do "theories" matter?

Although the Concept-Driven approach, is a designerly approach, the theories are central concerns. Theories in this approach are as abstracted and condensed knowledge about fundamental entities of HCI/design discipline, which is the interaction. Although, the theory construction is not often viewed as a main purpose, contribution nor as an essential part of a design activity – especially in practice – the design process or the activity itself have demonstrated the potentialities to lead to theories. A very well-known example of this kind of theory construction is Dieter Rams's "10 principles of good design"[2]. Which is a theory built by repeating the same process of design over and over again. A theory that is built through addressing design research questions and through this process, a design activity can produce knowledge. In Concept-Driven approach also the focus is mostly on the process of theorizing than the notion of theory itself (Stolterman and Wiberg, pp. 100).

A designerly way of theorizing often can happen in two different ways: 1) theorizing the process or the approach itself, so they can be replicable in different design situations; 2) theorizing by using and testing the outcome –i.e. it could be the final product or a very early

[2] www.vitsoe.com/us/about/good-design - Retrieved on January 2018.

prototype. The second one is the closest approach to the research-through-design approach, where making, probing and prototyping as a design activity becomes an aid to conduct research and also construct theories (Zimmerman, Forlizzi, Evenson 2007). This is also valid in Concept-Driven approach, except that it is intended specifically to theorize the interaction.

2.2 Methodological steps

The methodology of my research is composed of four sections of 1) “Concept Defining”, 2) “Concept Situating”, 3) “Concept Appropriating”, 4) constructing theories. (Figure 4)

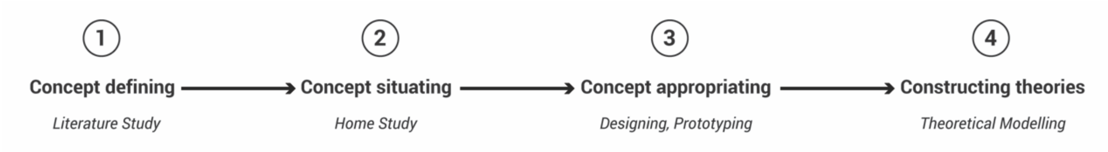

Figure 4: Methodological steps.

Concept Defining

I explored, studied literature and existing body of knowledge mostly within the fields of design and HCI (Human-Computer Interaction), even though at some points, I needed to study also cognitive psychology, geography and material culture studies. I was interested mainly to find out two things: 1) to understand the connections between physical artifacts –which they can become also computing and smart– and reflective thinking; 2) to understand the connections between reflection and behavior change.

After a careful study of literature, I found areas that lacks or contain little studies, which is normally the result of a literature study. According to these findings and also my research questions, I found and defined a theoretical concept. A theoretical concept, yet very broad at this stage, about the *tangible and computing artifacts that can stimulate reflective thinking in user.* Consequently, a first research question has been stated: What physical, digital, interactional characteristics should an artifact have in order to evoke reflection in user? As the point of departure of such physical artifacts is the category of “Smart Object” – computing everyday objects that can receive, sense, collect, elaborate and send data to other objects and people through Internet connectivity – so, I sought to describe the concept, starting from Smart Object’s characteristics. In doing so I tried to see what additional characteristics a Smart Object can have in order to stimulate reflective thinking in user, or in other words become a ***Tool for Reflection***. I describe this step extensively in chapter 3.

Concept Situating

For designing a *Tool for Reflection*, similar to designing any other artifact, there is a need to situating the concept: a study of the nature of physical, and cultural context of use. Then an artifact or system is being designed, according to that specific context and environment. The general characteristics and definitions of such environment, for instance its everyday objects, interactions and activities undertaken within its structures play important roles for successfully designing an artifact. In addition, for designing artifacts and systems for behavior change, a target behavior has to be selected. So, I first study home environment as a potential context for *Tool for Reflection*. Then a target sustainable behavior has been selected: urban mobility behaviors. I used different means for this study, conducting a questionnaire, interviews and a workshop.

Place

Home is a complex environment. Its physical and architectural structure enable certain behaviors, create spaces for certain activities and contains emotions, feelings and memories. I went through an analysis of home spaces – e.g. kitchen, bedroom, bathroom, entrance, etc. – creating three main categories of 1) intimate places, 2) family places, 3) in-between places. Among these categories, I picked the in-between places which are architectural spaces situated in home environment, but 1) do not manifest the characteristics of intimate spaces nor those of family spaces, 2) are the closest ones to the outdoor spaces – e.g. balcony, home entrance. Furthermore, a participatory session has been organized involving 12 participants. The main purpose of this session was to studying the activities carried out and objects that are being used in home spaces and in particular in in-between places, in order to aid the selection of an appropriate object. An *in-between place* and an everyday home use object have been chosen, situating the concept.

Behavior

A survey has been conducted among people who live specifically in Turin's urban area and more generally in Piedmont region *(Regione Piemonte)* in Italy. The main purpose of this questionnaire was to assessing the sustainable and pro-environmental behaviors of the Piedmont region inhabitants. We received 406 respondents, among them 52% female, and 48% male. They are geography distributed as follows: 47,2% live in the city of Turin, 27,2% live in Turin province and a 25,6 reported that live within other provinces in Piedmont. The questionnaire consisted of 26 main questions and they were mainly aimed to address these 5 areas: 1) Demographic distributions; 2) Home architectural spaces; 3) pro-environmental behaviors; 4) their perception about their pro-environmental behaviors; 5) their tendency towards having a computing and smart device that help them to change behaviors. Among these main categories, the category of pro-environmental behaviors results the core area of the questionnaire with a total of 44 sub-questions asking about 1) altruistic; 2) water consumption; 3) energy consumption; 4) urban mobility; 5) food consumption and 6) recycling behaviors.

The result of this questionnaire, reinforced data already existed in literature about issues regarding urban mobility behaviors in Turin (ISTAT 2016). One of the result shows that although respondents are quite good in carrying out some pro-environmental behaviors, such as in energy or water consumption behaviors, respectfully 69% and 59%, they seem that are not good in mobility behaviors – just 39% reported to having multimodal and sustainable urban mobility behaviors. So, the urban mobility behavior has been chosen as a target behavior.

In the same questionnaire, we had two other sections, that I believe reinforced and validated the concept of *Tool for Reflection.* In one of them, we asked participants whether they are willing to purchase "Smart Object" to help them to be more eco-sustainable and 60% confirmed that they forget to do such eco-sustainable actions and would use an object that can help them to modify their behaviors towards a more responsible manner. In another section, we asked about their general perception regarding their behaviors and 50% reported they believe they are thoughtful about environment at a very high level, 47% reported they are not at all thoughtful and feel guilty about it.

Concept Appropriating

After situating the concept – *Tool for Reflection* – by choosing a place, an artifact and a behavior, I went through the actual two steps of: 1) designing and 2) prototyping process of the artifact. Whereas the concept has been appropriated and realized through sketching, technical drawings, material selection, machining and/or craftsmanship techniques selection, building the physical structure and finally makes it working. The purpose of "Concept Appropriating", was actually to see an early example, a model of *Tool for Reflection* out there, in the world, as it manifests in a simple and everyday object. So, the prototype served for:

> "… 1) traversing a design space, leading to the creation of meaningful knowledge about the final design as envisioned in the process of design, and 2) prototypes are purposefully formed manifestations of design ideas." (Lim, Stolterman and Tenenberg, 2008)

During the designing step, a study of feasibility on physical forms has been conducted. This study not only concerned the overall form of the lamp, but also the aesthetical and functional details, patterns and modularity of the lamp have been carefully considered. The study of light behaviors, which manifest through the physical structure of the lamp, has been actually developed in parallel with form study.

A lamp prototype has been built according to the physical forms and light behaviors that have been defined in designing step. The lamp's materiality and its physical structure, enables both the experimentation with the physical modular units, and lights behaviors.

The interactional and physical properties have been realized according to the physical characteristics defined previously in the “Concept Defining” phase. However, many details have been added during designing or prototyping if needed, similarly some details removed if not feasible. A more detailed description of the “Concept Appropriating” step can be found in the chapter 5.

Constructing theories

This is a divergence phase, during which I went through a different analysis of the interactions with the lamp prototype. In this step, I changed the approach, from the study of the physical and interactional properties of the artifact that had been defined in previous steps, to a study of relationships that it makes with other entities which is connected to. So, a relational approach to designing and developing interactive artifacts, in particular, for designing interactive artifacts for reflection has been suggested.

To this aim, first some main and existing relationships with computing and IoT artifacts and systems have been analyzed and modelled: namely the *augment me*, the *comply with me* and the *engage me*. Then and building upon those models and through an analysis of the lamp prototype, its physical structure and its light behaviors, I sought to make a model for relationship between a *Tool for Reflection* and user called *make me think* relationship. So, 1) I went through an analysis of the different levels of interaction between the lamp and other three actors namely: 1) the environment(s), 2) the user(s), 3) other artifact(s) and system(s) that the lamp exchanges –send and receive– information with.

A more detailed description of the “Concept Appropriating” step can be found in the chapter 5.

2.3 Epistemological notes

This section concerns about the methodological character of my research. I seek to frame and interpret the logic behind my research activities.

In any scientific or social research, usually two major ways of reasoning are involved: Deductive and Inductive reasoning. Inductive way of reasoning is about starting from a very particular and narrow subject and concluding to a more general result and output. The deductive way of reasoning goes the other way. It starts from general theories and facts, and it concludes with validation of hypothesis and robust results. While the deductive way of reasoning is a common way of doing research in pure sciences and engineering, inductive is more common in social sciences and humanities (Figure 5).

Figure 5: Deductive and Inductive reasoning.

However, any kind of research findings could be a result of whether one way of reasoning or a mixed of both. In addition, literature often refers to a third way of reasoning: the abductive. Abductive reasoning is coined by Peirce (1905) one of the founders of Pragmatism. Peirce did not use the term of "abduction" at first, but he referred to "hypothetic" as the third way of reasoning. He used the term of "hypothetic" for describing the nature of research, which starts with limited knowledge and hypothesis as:

> "… an argument which proceeds upon the assumption that a character which is known necessarily to involve a certain number of others, may be probably predicted of any object which has all the characters which this character is known to involve." (Peirce 1868)

Eriksson and Lindström (1997) affirm that:

> "… Peirce's logic of abduction is based on his philosophy of "the maybes" and vagueness."

So, the abductive way of reasoning is based on hypotheses, iterations, and vagueness. It needs different divergent and convergent steps as it shifts often from deductive to inductive or vice versa. (Figure 6) The character of abductive way of reasoning, sounds similar to the designerly way of thinking in many ways (Cross 1982; 1998; 2001; 2006, Dorst 2004; 2011, Plattner, Meinel and Leifer 2016). According to Peirce's abduction, the reality –the concrete– is not only about what exists and what is perceptible here, but also about things that can be realized, as possibilities, what in design is often called "concepts". In design thinking, also the way designers embrace the vagueness widely has been debated.

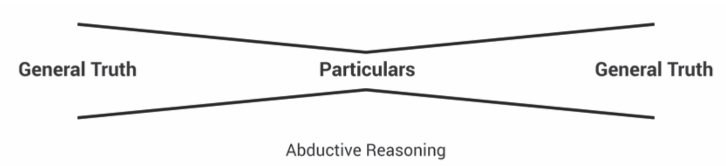

Figure 6: Abductive reasoning.

In design research, in particular, it is very common to use both ways of reasoning and shifting very often between them. So, this is mostly because, design as a process is usually faced with limited resources and limited knowledge about the problem. Because of this, designers have to hypothesize about the outcome and its consequences. For instance, when we design a product, we cannot be really sure about how it will affect its user physically or emotionally, or how it might change during time, what kind of meanings and memories it might hold for the user, because all of these are unknown facts, so we can only hypothesize and assume. Even during the design process, itself, we need to hypothesize and iterate several times between ideas, concepts and outcomes. Although in design research, the common belief is that design has its own way of reasoning and its own way of thinking and doing, looking at these other well-established scientific ways of reasoning, make us reflect that designing as a way of thinking and reasoning might be similar or a particular mix of them. A number of researchers have touched upon this topic. For instance, Goldkuhl (2012) and Dalsgaard (2014) consider pragmatism as a suitable paradigm for design research. Pragmatism is a very established school of thought which has been founded by Peirce and John Dewey as the main contributor (Dalsgaard 2014).

Pragmatism as the Philosophy of Designing

Pragmatism is a philosophy of science that places importance on ***why to*** do research in a given way (Morgan 2014, pp 1046). Pragmatism should be seen as a doctrine of meaning, and not as a methodology per se. (Denzin, 2012, pp 81). This philosophy points out, either to the importance of our research goal choices and also of the way we plan to pursue those goals. So, unlike what it has usually been assumed, the pragmatism is not only about ***what works*** and the practicability, but it is also about the ***why(s)*** and ***how(s)*** of a particular research goal. As Denzin affirms, pragmatism goes beyond of any methodology or problem-solving activity and it rests on the argument that *the meaning of an event cannot be given in advance of experience* (2012). In addition, Dewey states that our experiences are mainly: 1) habit-based: experiences that are unquestionable and automatic; 2) inquiry-based: when the situations become critical and we need to go through a process of reflective thinking and self-conscious decision making. Therefore, inquiry as research is a special kind of experience, it is reflective and thoughtful. It is a process by which beliefs that have become problematic are examined and resolved by action (Dewey 1933). Five steps of Dewey's approach to inquiry, 1) First is to find a problematic situation and 2) Defining details and particularity of the problem; 3) Developing actions that might solve the problem; 4) Evaluating those actions, their functions and consequences; 5) Taking action accordingly.

Abductive Reasoning in concept-driven approach

I believe my research methodology as a concept-driven approach used the abductive way of reasoning. As it shifted several times from deductive to inductive and vice versa. I started from general truths, so the well-established theories and literature in the field of HCI and design. I filtered them according to the main keywords of my research, behavior change, reflection, smart objects. Then I sought to see the relations between them in literature, for instance how many researches in literature deal with reflection and behavior change, or how many times reflection and smart objects, both appeared as author keywords. Then I searched among researches in the HCI about the physical materiality of the smart and computing artifact with the purpose of reflection and I identified a lack of studies in this domain. Then I defined the concept of *tools for reflection* and I validate the concept. So, I went from a general state of literature and theories studies and theories, to a particular state of *tools for reflection*. The next step is to situate the concept before actually design it. Then In order to design a *Tool for Reflection*, I needed to find a specific place within the home environment – as a broad architectural context of my research–. In addition, as *Tool for Reflection* evokes reflective thinking in user with the purpose of behavior change, I had to define also a target behavior. So "“Concept Situating"” step involved first a passage from the particular state of "“Concept Defining"” to a general state. In this general state I considered all places, activities and objects in the home environment, and also all sustainable behaviors of the inhabitants. Then this state converged to a particular state, where a particular place in home, a particular object and a particular behavior have been selected. This state continues towards the "concept apportioning", which is again a particular state of designing and prototyping an artifact. Then after this very particular state my research continued towards a new general state, which is the "constructing theories". (Figure 7)

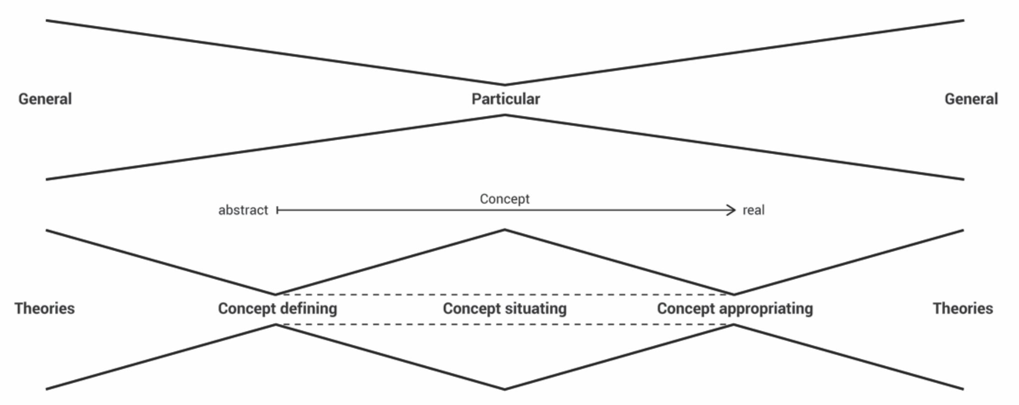

Figure 7: Abductive reasoning in this PhD research.

As it is illustrated in the figure 7, the three steps related to the concept develops from an abstract mode to a more real mode: "concept finding", "“Concept Situating"”, "“Concept Appropriating"”. These concept-related steps are placed at the central part of the model, where we see the particular state in my research, even though the "“Concept Situating"” itself has both general and particular states.

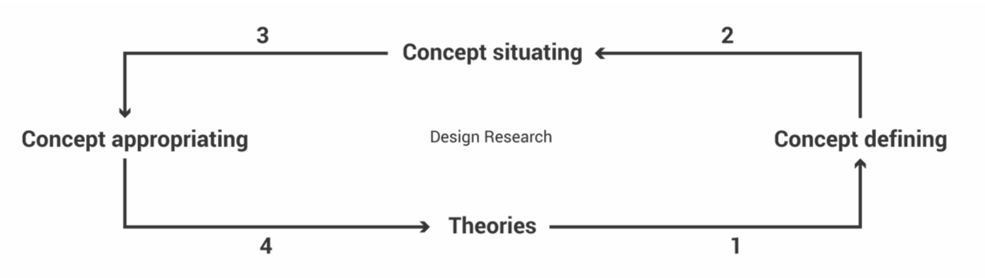

Figure 8: Design research in concept-driven approach of this dissertation.

In figure 8, I illustrated my research methodology, which is inspired by concept-driven approach. In this model, the design research at the centre of the model combines two different activities carries out during the process: 1) the research activity, 2) the design activity. The arrow number 1 shows the research activity of literature analysis that results in "“Concept Defining”". The arrows number 2 and 3 are related to the design activity, whereas an abstract design concept become real through prototyping. The arrow number 4 concerns again about research activity, which is the "constructing theories" step in my research.

So, in summary, two methodological steps of my PhD project (in figure 8: arrows number 1 and 4) consisted of research activities which are related to theories, either using or constructing theories. Other two steps consisted of design activities related to the concepts, from the "Concept Situating" to the concept appropriation (in figure 8: arrows number 2 and 3). So, the design research of my dissertation lies between two components of theory and concepts, which are in a mutual relationship and exchange to each other. (Figure 9)

Figure 9: Iteration Between Concepts and Theories.

Chapter 3

Concept Defining

3.1 Literature analysis

Reflection has been highlighted as a key dimension of design thinking and as an important ingredient of design processes. In this section, I take stock in our community's interest in reflection and I suggest that while it has been acknowledged as a cornerstone for design processes, it has been less explored as a basis for design outcomes. In Donald Schön's book, *The Reflective Practitioner*, the notion of reflection is highlighted as a key for meaningful design processes (Schön 1983). In his other works, Schön also highlights how reflection happens during the design process through reflective conversations with the materials of a design situation (Schön 1992). Accordingly, his work describes how reflective processes are entangled with behaviors and how the hands are part of exploring the materials; thus, reflection is at the same time entangled with the materials and artifacts at hand. In short, reflection is an activity that is inseparable from behaviors and artifacts (Bucciarelli 1984).

The importance of reflection not only has been highlighted by Donald Schön, but also has been a recurring topic for research in human–computer interaction (HCI). For instance, Stolterman and Löwgren confirm in their book, *Thoughtful Interaction Design*, how design thinking (i.e., reflections) is a key for designing good and meaningful interactive systems (Stolterman and Löwgren 2004).

As this literature study demonstrates, behavioral changes thus far have been explored relative to the design process and the design outcome. However, it is also interesting to see this idea of the entanglement of "reflection–behaviors–artifacts" as a basis for the design of "smart" things.

As formulated by Sherry Turkle, we usually consider objects as useful or aesthetic but see them less often as our companions, or as provocations of thoughts (Turkle 2011). Accordingly, if we can more thoughtfully design objects with the latter in mind, then they might better tackle problems that demand behavioral changes, such as in the areas of sustainability and health (e.g. Oinas-Kukkonen and Harjumaa 2009).

Methodology

To understand how the "reflection–behavior–artifact" relations have been expressed in the literature, a keyword analysis has been performed, first in Scopus database and then in the Association for Computing Machinery (ACM) library.

An initial search in the Scopus database found a total of 1,771 scientific papers about "Behavior Change Design"—mostly from medicine, computer science, and social science studies. Then, I filtered and categorized the results with following three keywords: 1) "reflection": 85 papers since 1966, mostly from medicine, computer science, and nursing studies; 2) "smart object": 15 papers, from computer science studies, since 2006; and 3) "tangible user interface": 8 papers from computer science studies, since 2005. Then a similar search has been conducted in the ACM library, which brought up a total of 1,884 scientific papers containing "behavior change" among their author keywords. I filtered them through the following keywords: 1) "reflection": 762 papers since 1971; and 2) "smart object": 71 papers since 1971. These keywords have been selected to construct the relation between smart artifacts, behavior change, and reflection. Although I also filtered the results using "tangible user interface," they have been excluded from the analysis because most of the resulting papers were focused on the operation of the tangible user interface and not about how such interfaces can influence human behavior.

I also made another refined and more focused keyword study in the ACM library to filter and categorize the literature on designing systems that promote behavior change in HCI. In particular, I sought to find out how many times behavior change (BC), sustainable behavior change (SBC), health behavior change (HBC), and reflection behavior change (RBC) have appeared among the keywords of the ACM library publications in the past ten years (Figure 10). Specifically, BC is the extended notion that covers the whole range of research areas on behavior change design; the others are related to specific areas of design for consumer behavior changes—namely, SBC in sustainable energy and water consumption; HBC in health, food, and sport; and RBC in the quantified self and self-reflection on personal data.

Among the different areas related to behavior change, HBC proved to be one of the growing ones, and more explored than the others. SBC, although currently shown as one of the areas with the lowest number of publications, is slightly increasing. Finally, the RBC line shows one of the highest percentages of incremental growth. Although the line has fluctuated since 2007, it has continued to grow, registering in 2014 its highest value and a growth rate of 22%, compared with the same value for the previous year.

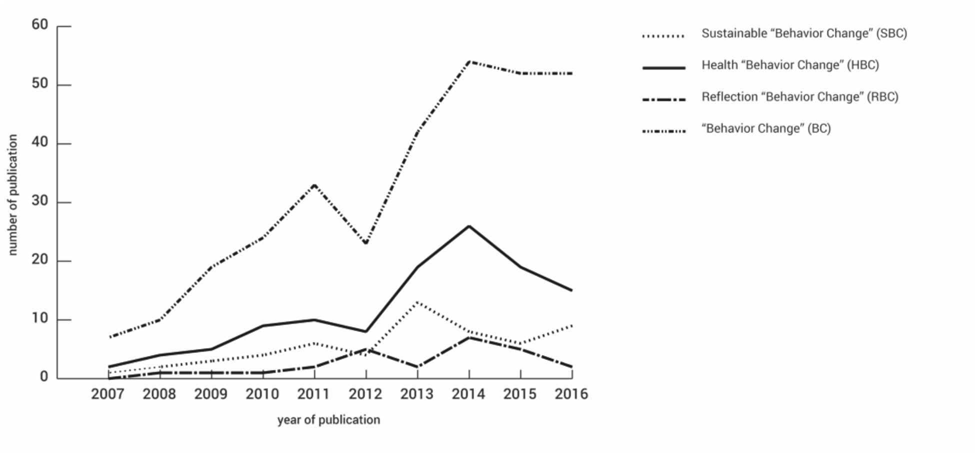

Figure 10: Behavior change researches 2007-2016.

To capture the relevance and the relation between BC and reflection, I also conducted a keyword analysis in the latest ten years of ACM publications for the keywords of reflection behavior change (RBC), reflection health behavior change (RHBC), and reflection sustainable behavior change (RSBC). Figure 11 shows the growth, as well as the fluctuating trends, of all these keywords. In particular, the number of papers including the RHBC and RSBC keywords is increasing and fluctuating over the years.

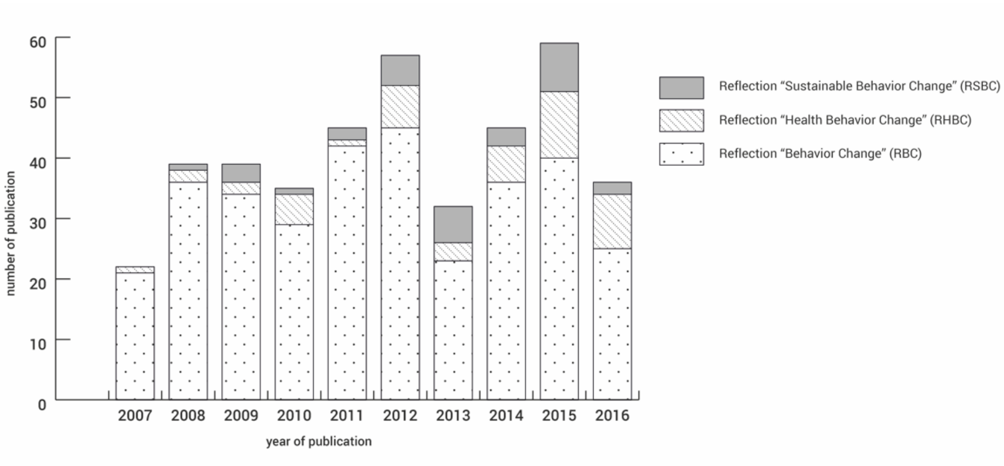

Figure 11: Reflection and behavior change researches 2007-2016.

Lastly, Figure 12 shows the relevance of available literature that explicitly deals with smart objects (SO) and with the relationship between SOs, BC, and reflection. It shows that the number of papers including the keyword SO has been increasing through the years, but only a few of these papers are related to the notion of reflection (RSO), and 13% of the total publications on SOs also has BC among the author keywords (BCSO). This percentage might reflect that research on SOs is mostly focused on designing the technical features of SOs rather than exploring the ways that SOs can affect the users and their behaviors.

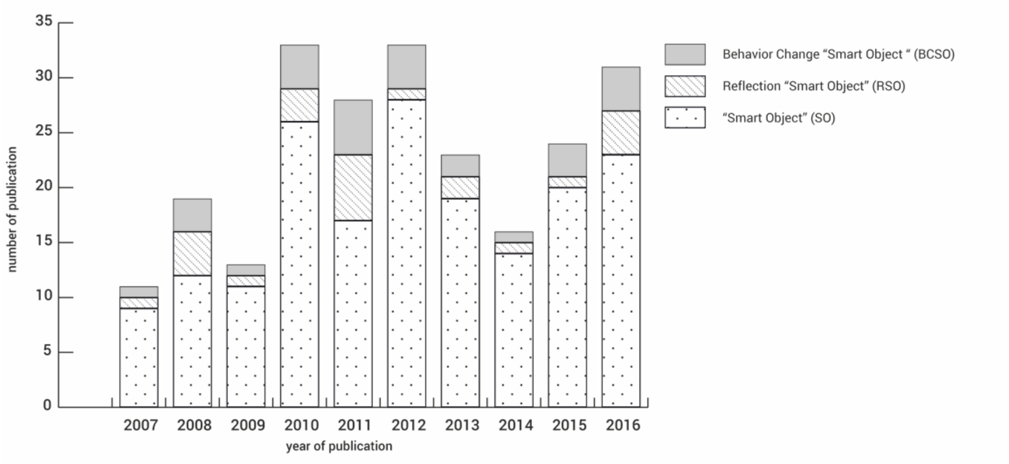

Figure 12: Reflection, behavior change and smart objects researches 2007-2016.

In summary, the BC keyword is attached to a number of papers. However, just 5% of these papers is associated with the application of reflection, and just 4% of the total publications deal with the possible relation between reflection and SOs. Although this topic is very new, with a relatively small number of papers, it represents one of the growing areas of interest within the HCI community of researchers.

What is reflection?

Reflection as a way of thinking is not only an individual and internal process, rather reflection requires external stimuli: the objects, other people, activities and the environment, which are also important in that process (Salomon 1993; Rogers 1997). Reflection demands continuity, it helps people to understand a situation deeply, in order to take careful and informed courses of actions for change (Sengers et. al. 2005; Schön, 1983; Dewey, 1933). Reflective reasoning is a deep, slow and effortful process (Norman 1993, pp 25). It requires moments of quiet, but also the aid of external support, such as writing, computing tools, books, etc. Unlike the experiential thinking, reflective thinking is not autonomous or reactive, it is about concepts, reconsideration, planning and decision making. It is not about the elaboration of the information structure already existed in our brain (Norman 1993).

In his seminal work "How We Think," John Dewey describes reflection as a deep consideration of experiences and actions in order to discover connections, that is, relations between things (Dewey 1933). Reflection demands time and continuity; it helps guide people to understand a situation deeply, allowing them to take careful and informed courses of action for change. Reflection as an activity, is not only an individual and internal process, but it also requires external stimuli: objects, other people, activities, and the environment (Hutchins 1997, Salomon 1993, Rogers 1997).

Reflection and behaviors

Reflection as a driver for behavior change has been largely investigated in learning, professional, and organizational contexts (Dewey 1933; Schön 1983; 1999, Sugiyama and Meyer 2008, Georgiev 2011).

Generally, it affects the learning process by enabling the review and merging of a series of previous experiences and events to generate a better understanding or to gain some sort of insight. In particular, Schön in 1983 stated that reflection is a type of “thinking about” that enables a kind of problem solving involving the construction of an understanding and reframing. Therefore, reflection is a form of thinking that reframes the situation and enables different kinds of decision making that would otherwise be unachievable. This perspective emphasizes the role of critical thinking as an essential tool to allow people to make conscious value choices in their attitudes and practices. It concerns bringing unconscious aspects of experience to conscious awareness, thereby making them available for conscious choice (Sengers et. al. 2005). Reflection has been also considered as a *tool* to provoke a new way of thinking, so that some interactive experiences are said to provoke reflection or to invite it (Gaver 2003).

All these contributions agree that the reflective practice requires an external entity, usually another person as a *mentor*, who is able to propose appropriate stimuli and questions at the right time. Sengers et. al., in particular, reflect on the role of technology in this sense by defining reflective design as a practice that combines the analysis of the ways in which technologies reflect and perpetuate unconscious cultural assumptions and the design, building, and evaluation of new computing devices that reflect alternative possibilities Sengers et. al. 2005).

Hence, two distinctive but related topics emerge. One is about the design activity and concerns the designer’s reflective activity as a professional practitioner (e.g. Löwgren & Stolteman 2004; Shön 1983; 1996, Dewey 1933). The other is related to the artifact and to technology that is able to evoke reflective kinds of thinking in people. In the latter, reflection becomes the primary intent and a concept for the design of such artifacts, and it is the main focus of this dissertation. Reflection that mediates between the user and the user’s behavior.

Reflection and behaviors in HCI

The notion of reflection is of great interest to the HCI community in several research areas, especially as a way to do research in informatics and also as a way of using technology to support learning and playing (Baumer, 2015; Price et. al. 2003; Anderson and McLoughlin, 2007; Rogers and Muller, 2006)

It also has been the subject of research in the area of behavior change design in health and sustainability, in critical design, and in the interaction design process in general. Research in this area ranges from the theoretical to the practical and to tangible contributions. The theoretical contributions are mostly about the reflective process of designing interactive artifacts using new methods and tools for supporting this process. Few works are about using reflection as an alternative to persuasion-based design systems. Meanwhile, in practical and tangible contributions, research considers, for example, eco-feedback technologies and ambient lights as a means to reduce energy or water consumption by providing tangible, mostly lighting feedbacks on mobile devices or through a tangible artifact in the domestic environment (Malacria et. al. 2013; Gao, 2012; Brynjarsdóttir, ett al. 2012; Froehlich et. al. 2010; McKinnon, 2016; Bardzell etl al. 2012; Dunne and Raby, 2008).

In these domains, "reflection" refers to the action of reflecting on information provided, being informed about the consequences of an action or behavior, and creating puzzling and surprising effects (Fleck 2012; Baumer 2014). The activity of reflecting on past actions is called reflection-on-action; it differs from reflection-in-action, which is related to reflecting while doing an activity. Thus, the first is about recalling memories and experiences and then reflecting on them, while the second concerns reflecting on the activity while the action is being done. For the reflection- on-action, data are visualized to bring them into mind so they can be used for further reflection; the reflection on the data about an activity reduces the need for storing and memorizing personal experience but encourages recalling them when required. To design for such purposes, relevant conditions for reflection should be considered, which are time, motivation, skills, guidance, and encouragement (Gustafson, Bennett 2004). From this perspective, reflection as a temporal process needs time, as well as other external factors that guide and encourage people toward reflection (i.e., a mentor). Moreover, social interaction also seems to have a relevant role because it allows for the possibility of talking with other people about experiences, which helps in the recall of memories. Therefore, interactive systems for behavior change increasingly focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action (e.g. Plodderer 2014).

The representation of social traces, social support, and collective use, which are essential parts of behavior support systems, goes beyond the mere representation of sensory data collections; it also seeks to provide structured information frameworks and patterns to enhance reflection. In this context, the relationship between data visualization and reflection has already been investigated in the HCI literature over three different perspectives. The first is the representation of data that stimulate reflection—for example, through the form and the degree of ambiguity of data visualization. Here, lists support ordering of information, trees show hierarchies, and tables show relations between data points. The second is the way people perceive data representation—for instance, as effecting accountability or playfulness vs. intrusiveness or guilt. The third perspective considers the social and personal influences of data visualization, such as patterns of social learning and facilitation, competition, cooperation, and recognition. (Li et. al. 2011; Odur et. al. 2014).

Sas and Dix, consider reflection as the final aim of the design process, so they propose to design technologies to support people’s reflection on personal experiences (Sas and Dix 2011). Fleck and Fitzpatrick consider reflection to be not just the main purpose for design, but a medium to reach a purpose. Therefore, technology is not used just to cause reflection, but also to help reach a higher level of reflection that is required for behavior change as a purpose and intent of the technology.

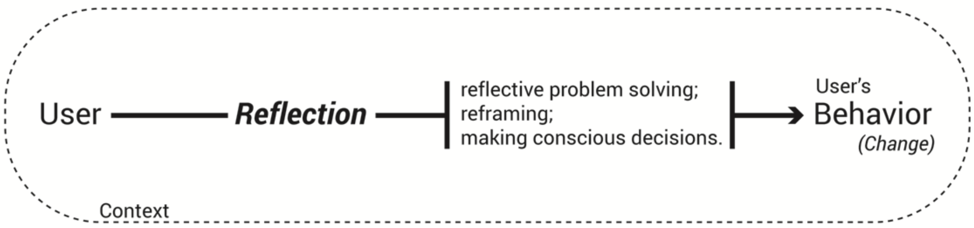

Figure 13: Reflection on user’s behavior.

To move forward, we need to illustrate the role of the artifacts in relation to this model (Figure 13). Accordingly, the next section is dedicated to this topic, providing an overview of the use of interactive and smart artifacts to influence behavior and evoke reflection.

Artifact

What is an artifact? This topic has been debated for many years, and so I start with few historical notes. Aristotle divided existing things into those that “exist by nature” and those existing “from other causes.” The latter concerns designed things and artifacts, which has been considered as the outcome of any design process. (Binder et al 2011)

According to Nelson and Stolterman, designed things do not exist by nature; rather, they become created by humans according to needs, intentions, or irritations (Nelson and Stolterman 2011). Definitions of artifacts also stretch across other orientations in literature. For instance, many seminal works define artifacts according to their goal and functions (Simon 1996, Crilly 2010). Gero extends this definition, crafting the FBS (Function, Behavior, Structure) ontology that describes artifacts based not only on their goals and *functions* but also according to the *behaviors* and *structures* that are necessary for achieving goals (Gero 1990). Thus, what artifacts are for depends on the way they behave and the *structure* that enables these behaviors. However, these *behaviors* and *structures* (e.g., shape, color, and compositions) influence the use, and the user’s activity and behavior, through the interaction and use; the latter, the interaction and use, in most cases is closely related to the artifacts’ affordance (Gibson 1977, Norman 1988).

Hence, artifacts have been seen as passive tools for achieving predefined goals through use and function. They also are seen to influence human behaviors, whether to support or to change them. Artifacts also are able to evoke thoughts in different ways—for instance, through appearances, materials, behaviors, affordances, and functions, as well as through memories and experiences that they hold (Turkle 2011).

What happens when the artifacts become interactive, smart, and connected to the Internet? (Verplank 2009). If we see artifacts no longer as passive tools, what thoughts do they evoke? How can they change users' behaviors instead of supporting them by evoking thoughts and reflection? In this dissertation, I focus on these perspectives and questions about artifacts.

Artifacts and human behaviors

In general, four basic factors play important roles in human–artifact interaction: the artifact, the user, the user's goal, and the context in which the interaction takes place (Shakel 1959). These factors can also be extended to the network with other artifacts and people who are involved in or affected by the artifact's use, including any artifact–service combination (Wever 2009).

The idea of designing for users' behavior has been developed in studies on design by Donald Norman (e.g. Norman 2007). His early works introduced human cognitive and psychological factors into design research (e.g., the concepts of affordance, constraint, and feedback) that later became the basis for interaction design (Kolko 2011). The notions of "usability" and "experience" later became the two key aspects in design, pointing out the need for a deep understanding of the way people interact with artifacts, for making the designed artifact's use as easy and pleasant as possible, and for supporting users' behavior.

In terms of the design process of such artifacts, the common factor among the approaches is that the design practice is always intended to guide or change a behavior. Although the design process originates from different sources, the expectation is that a designer's intent will be realized in certain user behavior during or after the user's interaction with the artifact.

The idea of using the features of an artifact to mediate or to evoke change, instead of supporting a user's behavior, has been expressed in a number of different approaches, including Lockton's Design with Intent and Niedderer's Performative Objects (Lockton 2010, Niedderer 2007; 2013). In design with intent, in most cases an artifact is designed in such a way as to avoid a particular behavior by users. Meanwhile, the performative objects (POs) invite users to behave in a particular way. In designing POs, designers also design user activities that do not occur independently from the product. In both examples, the artifact function is not to support a user's habit or behavior, but to help users avoid it or to invite some other kind of behavior through unfamiliar uses and functions—to be evocative rather than supportive. This lack of familiarity puts users in a new condition and guides them through a process that makes them think about it, by manipulating and sensing the artifact. Thus, the artifact's characteristics (e.g., textures and shapes) play fundamental roles. (Figure 14)

Although digital artifacts have some physical parts, they have also lost or deemphasize some physical qualities, such as some material qualities, textures, and patterns (Wiberg and Robles 2011). To restore the quality of physical interaction with materials, many researchers have worked on the sensorial properties of the digital artifacts, including attributed color and sound, to shape particular perceptions and experiences and to affect human behaviors (Schifferestein and Hekkert 2008). Products' intentional sounds, used to improve the user–artifact interaction by including a means of feedback, are proven also to influence user experience and behavior through possible auditory semantic associations (Egmond 2008).

In this sense, designers have various opportunities, in applying technologies, to stimulate human senses in ways that go beyond just visual and tactile perception (Sharma et. al. 2008). These opportunities have proven to be useful in the creation of novel interactions. For example, Gaver's auditory interfaces and Kramer's auditory displays explore the potential of auditory periphery interaction (Gaver 1998). Bakker's works, in particular, focus on physical interaction and auditory interaction in the periphery of our attention (Bakker et. al. 2015).

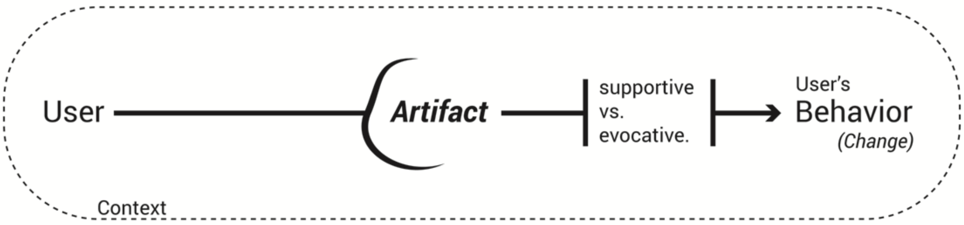

Figure 14: The role artifacts play in shaping user's behavior.

Artifact and reflection

Although, the idea of using computing artifacts as tools for enhancing learning process, creativity or for aiding reflective thinking is not new, literature currently does not present the material features of such artifacts. It neither identifies any design guidelines. In this section, I briefly introduce the available concepts and theories, which argue about physical and smart artifacts as mediums of reflection.

In particular, designing the features of a computing and interactive artifact in a way that can foster thinking and cognitive development has been the subject of many researches in cognitive and learning science areas. For instance, Pea's concept of "cognitive technology", is one of the early examples of concepts for designing such artifacts (Pea

1985). This concept employs using of computing technologies as *"mediums" [tools] that help transcend the limitation of mind, such as memory, in activities of thinking, learning and problem solving".* Cognitive or mind tools stand for learning and thinking *with* instead of *through* computers, which enable learning *with* interactive technologies as intellectual and active partners. They are designed and adapted to the learner environment in order to engage to a deep reflective thinking and higher-order of critical and meaningful learning. This engagement helps also learners to generate ideas in the context of problem solving (Lajoie and Derry 1993; Jonassen and Reeves 1996).

In this section, I briefly introduce the available concepts and theories, which argue about physical and smart artifacts as mediums of reflection.

The concept of slow technology concerns a category of physical artifacts that are not "used" at all but that instead support activities located within the environment. Slow Technology is an approach in HCI that emphasis on the role of technology that can foster moments of reflection, instead of efficiency in performance (Hällnas 2011). The "slowness" of technology as a feature has been associated with the simplicity and modest appearance of the artifacts (similar to Weiser's calmness of technology, 1991); it is also based on concepts such as appearance, presence, expression, and environmental interaction. These factors evoke reflection and can influence users' behaviors if reflection reaches its higher levels (Siegel and Beck 2011).

Furthermore, Dietrich and Laerhoven (2016), demonstrate the mediating character of wearable technologies for the purpose of reflection. They have merged the concepts and theories about the mediated role of technology with Dourish's embodied interaction (Verbeek 2014). Embodied interaction is the type of interaction that occurs as a result of the realization and concretization of data, and it may overlap with tangible interaction in various forms. Tangible interaction combines the properties of both physical and digital entities through the use of physical artifacts to represent and control digital data (Ishii and Ullmer 1997). Embodied interaction views tangibility as a key means of interacting with the physical world, but it takes a broader stance by envisioning meaningful interaction with technology as inspired by both the physical and social phenomena of everyday life (Dourish 2004).

Using tangible artifacts as media of reflection also has been explored in other ways. For instance, Lover Box is a tangible artifact that encourages couples to reflect on their relationship; Data Souvenir is an augmented book with hardware and software that applies environmental psychology to allow or encourage reflection in the home environment (Aipperspach et. al. 2011; Thieme et. al 2011; Gennip et. al. 2015; Mols et. al. 2016).

Despite the growing interest in and availability of these technologies, designing for reflection is still in its early stages. Even though tangible user interfaces are becoming diffused in smart artifacts, exploration and study of the novel forms of tangible interaction that can promote reflection and, in particular, of the role that materials play in that sense, is still lacking (Figure 15).

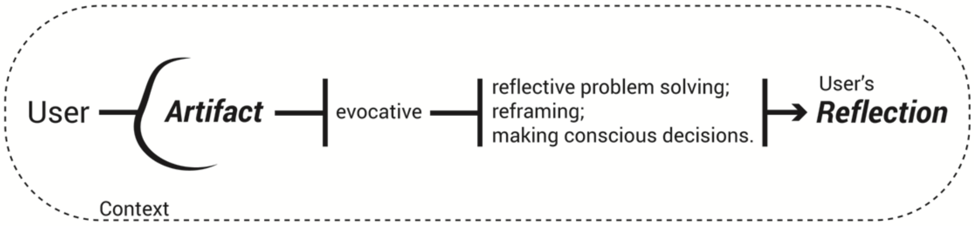

Figure 15: The evocative role of artifacts.

Smartness in artifacts

Research on smart artifacts and the Internet of Things began nearly two decades ago, with Mark Weiser's vision of Ubiquitous Computing (Weiser 1997). Emerging technologies have been enabled using a range of computationally enhanced and Internet-connected devices, commonly called "smart artifacts," "semantic devices," and "connected artifacts," among other terms. They can sense, log, and interpret what's occurring in their context and can interact, intercommunicate, and exchange information with other artifacts, and also with users (Kortuem et. al. 2010; Fortino, et. al. 2012; Sabou 2010).

Smart objects have been explored and defined in various research fields, such as business, ambient intelligent and web semantics (Marta Sabou, 2010; Kortuem, et al. 2010) and their four properties are defined as the most relevant: 1) **Reactivity:** smart objects can understand events in a given physical representation; 2) **Proactivity:** smart objects can act autonomously and control the situation; 3) **Being Preemptive:** smart objects can predict errors and faults in order to remove unpleasant surprises for user; 4) **Interactivity:** smart objects can converse and interact with the user in terms of input, output and feedback in a simple and intuitive way.

The result of this extensive literature study, confirms further that although the reflection has seen a growing interest in the HCI community, there are few design works about it – i.e. design projects and theoretical investigations about design of physical and smart artifacts that can evoke reflection.

3.2 Concept: *Tools for Reflection*

The idea of using computing artifacts as tools for enhancing learning process, creativity and especially for aiding reflective thinking is not new. In particular, designing the features of a computing and interactive artifact in a way that can foster thinking and cognitive development has been the subject of many researches in cognitive and learning science areas.

For instance, Pea's concept of "cognitive technology", is one of the early examples of concepts for designing such artifacts (Pea 1985). This concept employs using of computing technologies as *"mediums" [tools] that help transcend the limitation of mind, such as memory, in activities of thinking, learning and problem solving".* Cognitive or mind tools stand for learning and thinking *with* instead of *through* computers, which enable learning *with* interactive technologies as intellectual and active partners. They are designed and adapted to the learner environment in order to engage to a deep reflective thinking and higher-order of critical and meaningful learning. This engagement helps also learners to generate ideas in the context of problem solving (Lajoie and Derry 1993; Jonassen and Reeves 1996).

In summary, it has been debated that various interactive technologies seem to be effective in learning and thinking, either *through* and/or *with* them. In this regard, the learning *with* interactive technologies or cognitive tool approaches are the focus of more researches than ever before. As Beaumie and Reeves (2007) built on the Salomon's concepts of distributed cognition (1991;1993) and argued:

> ".. the learner, tool, and activity form a joint learning system, and the expertise in the world should be reflected not only in the tool but also in the learning activity within which learners make use of the tool."

Thus, as it is stated in the above quote, the learner or the user, the computing artifact and the activity or task are components of the learning system and which is about a system of relations as I have discussed in the earlier sections. Considering also the concepts of cognitive tools and according to the theory of distributed cognition, the way cognition is distributed, is first determined by the intentions of cognitive tool designers. And then consequently, it is determined by the tool's characteristics, for instance by tool affordances, forms and behaviors (Shackel 1984).

Hence, a cognitive or a mind tool is essentially a physical artifact that should be designed in a way that accomplish their functions and communicate designer's intentions (e.g. Crilly 2010). In this regard, the reflective thinking is the function of the tool and the designer's intention. So, similar to any other physical artifacts, it needs to be designed in order to function, thus it requires to have particular characteristics that enables that function – supporting cognitive activity and reflection in user.

The result of this extensive literature study, confirms further that although the reflection has seen a growing interest in the HCI community, there are few theoretical investigations about design of physical and smart artifacts that can evoke reflection. In particular, there is a lack of studies in characteristics of such artifacts. Therefore, the *tools for reflection* as the concept of my PhD dissertation has been emerged after this analysis of literature. *Tools for reflection* are physical, tangible, computing and smart artifacts, able to log, sense, collect data and provide feedbacks similar to smart objects. They are tools, as they help us to do an activity, or are equipment used to make or repair something.[3] We understand tools by using them *in order to* carry out a task, so we understand them in a purposeful way. For instance, pen is a tool, and we understand it as such, because we must use it, in order to write. But tools also have relational properties, it means we can understand them and their functionalities in a collective sense, because they are in relation to other entities. For instance, we use a pen in order to write on a paper which, is on a table, which is located in a room.

This dissertation opts such an approach towards designing for reflection. It considers computing and smart objects as tools, which means they should be touchable, usable and understandable *, in order to* support reflective thinking as a task.

With respect to the HCI researches that have investigated on the ability of smart objects to change human behaviors, those abilities are able to offer an opportunity of influencing reflective behavior of users. This is relevant because the ability of artifacts to provoke peculiar thoughts and reflections, helps and guides users to make decisions consciously, instead to follow fixed and pre-defined rules and steps. This is also related to the design purpose of such products that to not only support people having an easier life but also having a better quality of life (Schifferstein, Özcan and Rozendaal, 2015).

To this end, as an attempt to define some characteristics of *Tool for Reflection*, I present here four augmented features building upon the features that characterize the analogue objects and the smart objects in literature. As illustrated in Figure 16. Similar to the augmented features that enable an object to become ‘smart’, this augmentation process transforms a smart object to a *Tool for Reflection*.

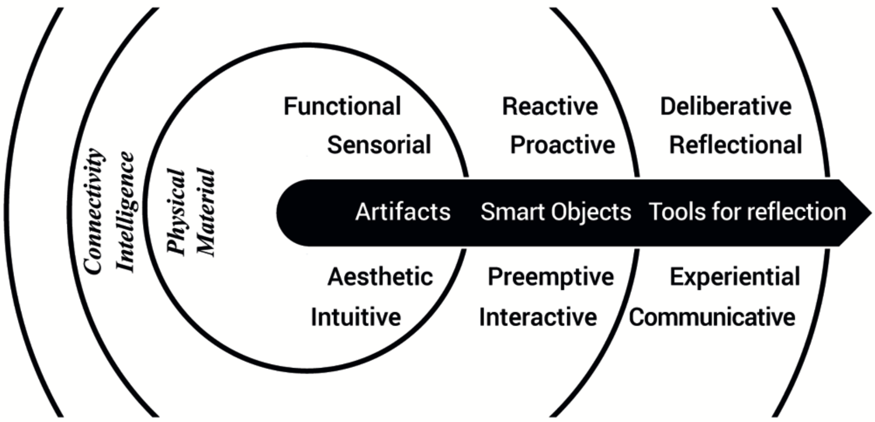

Figure 16: Characteristics of a *Tool for Reflection*.

[3] https://dictionary.cambridge.org/dictionary/english/tool - Retrieved in January 2018.

Deliberative

Tool for Reflection, is deliberative because it constructs their internal beliefs and opinions. A deliberative reasoning enables to hypothesize possible outcomes and to make decisions. It is related to the situated agents' reflective way of reasoning, as defined in the AI and multi-agent systems (MAS) studies (Gero and Kannengiesser, 2003). Being Deliberative is one of the *Tool for Reflection* feature that enables the construction and modification of internal concepts, beliefs and goals based on the previous experiences and perceptions.

Reflectional

This feature evokes thoughts and reflections in user through providing peculiar tangible feedbacks. It is related not only to the physical forms of artifact but also to the temporal forms (Vallgårda and Redström 2014). Since, *Tool for Reflection* perform both internal and external actions similar to any other situated agents, the external actions which are tied to the user interface, represent crucial factors concerning the Reflectional property. This is mostly because user perceives only external actions. These complex feedbacks, as perceived by user, demonstrate radical or incremental changes in the *Tool for Reflection* interface and external structure, such as changes in form, texture and color, are as a result of the Reflectional feature.

Experiential

Research has shown that the experiment with physical artifacts can enhance the reflection and increase awareness (e.g. Hornecker and Buur, 2006). Accordingly, a *Tool for Reflection* is Experiential, that has the ability of engaging the user into experimentation and exploration. Likewise, it is assumed that provoking user's reflection on personal data becomes more effective if the perception of information is not just limited to the user's visual perception, but also integrates the tangible interaction with information. This means the interaction should involve other sensorial capacities rather than just visual (e.g. Ullmer and Ishii, 1997; Shaer and Hornecker, 2010; Rinott, 2013; Houben et. al., 2016). In addition, the tangible representation of data, conversely of numerical data visualization, leaves open the interpretation of the information.

The Experiential feature of *Tool for Reflection* includes important drivers of reflection such as openness to interpretation and playfulness of engagement and exploration.

Communicative

Debates on the communicative character of computing technology is not new. Computers as constructive tools have been used for the purpose of learning in educational contexts (Papert and Kay, 1968; Kay, 1972) or for expression and communications of algorithms and models in network communications (Dourish, 2004b). In addition, in every design context, the Communication, allows artifacts to deliver the designers' intention as a message to the users, where *the sender* is the designer, who intends to transmit a particular *message* to a *receiver* (the user) through a physical artifact as a *medium* (Crilly et. al., 2008; Varduoli, 2015). According to this interpretation, "use" become as "writing", "reading" and encoding the message (Crilly et. al., 2008) and the medium modulation becomes essential because it is a particular form of transformation. Modulation is also defined as the carrier of information or the carrier of meaning in terms of embodied interaction (Dourish, 2004a). The modulation/communication/transformation process between *Tool for Reflection* and users creates a loop, wherein *Tool for Reflection* do not merely convey and transform the message, but are also able to receive and interpret them and resend the information to the user via encoding and decoding. *Tool for Reflection* together with users participate in the process and are able to redesign the artifact and personalize the "text".

Validating the concept through FBS framework

As an attempt to structure and validate the defined augmented features of *Tool for Reflection*, I applied the FBS model (Gero, 1990) that defines three principal design variables, namely: the Function (F), the Behavior (B) and the Structure (S). The F defines the intents of designing the artifact (What an artifact is for?); the B describes the attribute derived or expected to be derived from the S in order to achieve its function (What an artifact does?); and the S that describes the components of an artifact, which enable particular behaviors and defines their relationships (What an artifact is?).

The FBS framework has been already applied on various researches in different domains. On redesign (Chase and Liew, 2001) and engineering change management processes (Hamraz et al., 2014) as contexts of applications; in ontological term (Vermaas and Dorst, 2007; Galle, 2009) or to extend it so to include needs and requirements (Cascini et al., 2013). The model, in addition, has been also applied to understand the social behavior of the agents in MAS and AI (Gero and Kannengiesser, 2003). In particular, the S has been divided into two essential layers of situated (S^s) and fixed (S^f) structures. The S^s are those structures that change and transform according to input received from the environment and users and the S^f represent those that are not subject to change. In this view, agents' structures are illustrated from the designer's and other agents' perspective. However, the user is not specifically considered in his/her interaction, that defines a peculiar agent's perspective of observation.

Tools for reflection are intended to stimulate a reflective behavior among users, while they use and interact with them, hence the assumption is that the external layers of the structure play crucial roles. This requires introducing two new layers to the structure of agents (Figure 17).

The consequent introduced structures could be whether fixed ($S^{f\text{ - External}}$) or situated ($S^{s\text{ - External}}$). The $S^{f\text{ - External}}$ are for instance, hinges, pivots and junctions, which do not change and do not face any transformation according to the input from user and the environment. The $S^{s\text{ - External}}$ specify the external forms, textures, colors and any other perceptible components, which are tied to the tangible user interface and are subject to changes and transformations according to the input from users and the environment.

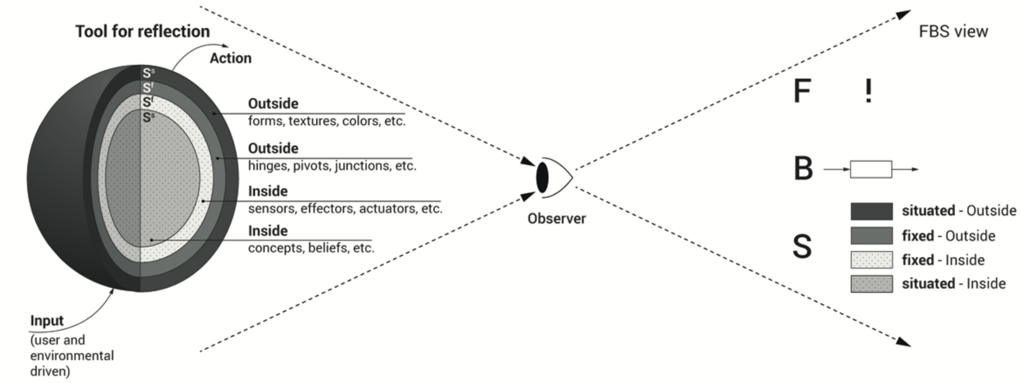

Figure 17: An FBS view of a Tool for Reflection (revised: Gero and Kannengiesser, 2003).

According to the FBS framework, each S should be designed in order to perform some peculiar B in order to achieve a particular F. In the *Tool for Reflection*' FBS model, F are considered as the same augmented features they hold in addition to SOs, namely: Deliberative, Reflectional, Experiential and Communicative. This set of *Functions* helps to achieve the primary intent or purpose of designing *Tool for Reflection*, which is to stimulate reflection (Table 1).

Some of those *Functions* are tied to the internal structures: if the observer who interacts with the structure is a user, there is very low amount of information available so that *Structure* and *Behaviors* may not be visible. In this sense, the *Function* of being Deliberative is tied to the ($S^{s\text{ - Internal}}$), which determines the agent's concepts and beliefs that remains invisible to the user. Some other *Functions* are related to the external structure on which there is a high amount of information available, since are perceptible through human senses: thus, the *Structures* and *Behaviors* become visible. Being Reflectional, for instance, is tied to the ($S^{s\text{ - External}}$) and ascribes the agent's form, texture and other sensorial attributions. This type of *Structure* is also situated and this means that it transforms according to the changes occurred within the ($S^{s\text{ - Internal}}$).

In Table 1, I describe a *Tool for Reflection* according the FBS model, so as to represent the augmented model of agent's view through the FBS variables. Through this model, moreover, it appears evident how *Tool for Reflection* perform three main type of interactions, namely: Social (*Tool for Reflection*-agent), Design (*Tool for Reflection*-designer), and Use (*Tool for Reflection*-user) interaction.

Functions (F) *What the artifact is for*	Behaviors (B_e) *What the artifact does*	Structures (S) *What the artifact is*	Observer
Being Deliberative	To reason slowly and carefully To construct concepts and opinions To hypothesize possible outcomes and external states To propose alternative actions To make decisions	**S^s : Situated-Internal:** Concepts Beliefs Goals (Building through Evolutionary Algorithms and Information)	Other Agents Designer
Being Reflectional	To provide tangible feedbacks to the user (e.g. change in form, color, texture, etc.) To provide multimodal interaction	**S^s : Situated-External:** Form Texture Sound Color Light	User
Being Experiential	To enable experimentation and discovery To enable personalization To enable construction/creation	**S^f : Fixed-External:** Physical and constructible modules Junctions	User
Being Communicative	To receive and send information To deliver the designer's intent as a message to the user To predefine and share knowledge (Social interaction with agents) To communicate its use (interaction with user: \affordance) To recall experiences and memories to user	**S^f_i : Fixed-Internal:** Electronics: sensors and effectors Actuators Power (Electricity)	Other Agents Designer
		S^f : Fixed-External: Form Energy provider devices …	User

Table 1: FBS requirements for design of *Tool for Reflection*.

Materials for reflection and materiality of reflective interaction

Designing for reflection is still in its early stages, but there is a great potential for it moving forward. The literature study I have presented in this dissertation illustrates the growing interest in the design community in the role of reflective thinking in design processes, and also its implications in behavior change processes. Interest also is growing in using computational artifacts as an outcome of the design process that are able to stimulate reflection in users. Further, and as we push the technological envelope further toward "tangible," "faceless," "smart," and "intelligent" artifacts, we should consider not only how to design these "smart" artifacts, but also how to consider the outcome of design as an interactive artifact with which to think (Janlert and Stolterman 2015). In designing interactive artifacts, the interests are shifting from virtual and immaterial to formal and physical representation of information.

This shift has opened up a new dialogue on material turns that acknowledges that computing is changing forms, and the substance of the interaction is changing as well. The perspective then widens to consider the relevance of materiality in interaction, not only investigating the physical substance and properties of the forms and materials, but also using this materiality as a resource for cultural, aesthetic, and thoughtful forms of interaction (Wiberg et. al. 2013).

In the design of interactive artifacts to think with, reflection, as a kind of thinking, can be considered a medium; as such, it can be incorporated into the materiality and material aspects of the human–artifact interaction.

In short, interaction design is increasingly about: 1) the design of interactivity as a process and activity in the form of interactive and smart artifacts; 2) exploring the potential of “reflection” and “behavior change” by designing novel forms of interactions; and 3) designing tangible and physical “smart” artifacts for the Internet of Things. As a result, there is a big opportunity here for using reflection as a design concept: designing “smart” and interactive artifacts, using the materiality and physical properties of the artifact to evoke reflection. The Figure 18 summarizes the result of this literature study. In this model, I suggest a focus on the evocative role of artifacts and on artifacts that can be designed to support reflection. This figure introduces two ways of defining design space for interactive artifacts to think with: 1) materials for reflection and 2) materiality of reflective interaction.

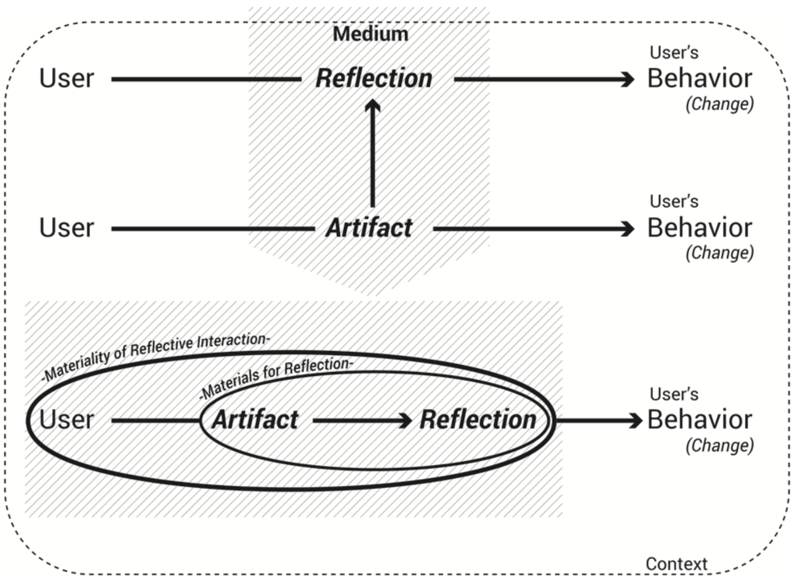

Figure 18: Design space for interactive artifacts to think with.

Chapter 4

Concept Situating

“Concept Situating” is a process of studying all aspect of a specific design situation, to which adjust a concept. In other words, “Concept Situating” support the design process by providing some requirements and knowledge needed in order to make hypothesis about the outcome. It is often about answering to “who”, “where” and “what” questions regarding the concept. For instance, for what behavior does a *Tool for Reflection* evoke thoughts? where is the place for using a *Tool for Reflection*? what every day object can become a *Tool for Reflection*? etc.

First a target behavior has been selected: urban mobility behaviors. I motivated my choice –although the context of my study was home environment, and urban mobility behavior is not a domestic activity– based on analysis of data from two sources: 1) ISTAT[4], 2) a questionnaire. I will describe how this choice has been motivated, in coming pages.

Furthermore, I needed to find out the nature and character of physical, and cultural context of use: the home environment as a broader context. In addition, I needed a more specific context in home environment, which sounds appropriate for reflection on that specific behavior – urban mobility behavior. The general characteristics and definitions of such environment, for instance its everyday objects, interactions and activities undertaken within its structures play important roles for designing a successful artifact. Moreover, an everyday object should be justified and selected according to that specific context and environment and also behavior. So, I first study home environment as a potential context

[4] The Italian National Institute of Statistics, a public research organisation, is the main producer of official statistics in the service of citizens and policy-makers. It operates in complete independence and continuous interaction with the academic and scientific communities. www.istat.it

for *Tool for Reflection*. I used different means for this study, conducting a questionnaire, interviews and a workshop.

4.1 Behavior

Private and personal means of transport report for a large amount of carbon dioxide emission. Transport currently causes about 27% of the total global carbon dioxide emissions (Agency IE 2009) which is having a significant effect on climate change and global warming. Consequently, many studies have been done and have shown that changing in people's urban mobility behaviors, even slightly, can help to reduce these harmful emissions (e.g. Vandenbergh et al 2008; Dietez et al 2009).

Turin's geographical, political and economic positions affect people's urban mobility behaviors. Turin city has 890.000 inhabitants which expand in the whole urban area about 2.1 million residents, from which about 1.9 million owns a personal car. Although the public transportation is growing in number of vehicles and services in the city of Turin, the number of km(s) travelled with public transport decreased about -21% since 2014. And this represents the biggest peak among other Italian big cities with Catania and Roma respectfully coming after (ISTAT 2016).

In April 2014, we conducted a questionnaire among people who live in Piemonte, Italy, and in particular Turin area. This survey had 2 main objectives: 1) to find out a pro-environmental behavior that needs to be fostered; 2) to understand if people are interested to purchase a computing and smart object that help them to change behaviors.

In total, we got 406 respondents, 51.6% female and 47.9% male. The geographical distribution of respondents reported as follows: 47.2% live in Turin city; 27.2% live in Turin province; 12.6% live in other provinces of Piemonte region.

The structure of the survey has been designed with 25 main questions:

- 5 Demographic questions.
- 6 Questions about their architectural structures of their homes.
- 6 Questions about their actual pro-environmental behaviors – 42 sub-questions on Linkert scale about 1) energy consumption; 2) water consumption; 3) food consumption; 3) recycling; 4) urban mobility behavior; 5) altruism.
- 5 Questions on their perception about their pro-environmental behaviors – 24 sub-questions on Linkert scale.
- 3 Questions about their interest for purchasing smart and computing products –24 sub-questions on Linkert scale.

The result of this questionnaire, further shows that a more sustainable urban mobility behavior in Piemonte region needs to be fostered. As it is shown below in the figure 19, sustainable urban mobility behaviors come after the altruistic behaviors. This reports that just 39% of people who live in Piemonte region, practice a sustainable and multimodal sustainable urban mobility behaviors. In analysis of the data, I considered the number of people who answered “always” or “often” to the questions in Linkert scale. For instance, to the question: do you use carpooling? do you share your car with your friends and colleagues? The answers were: Always 3.2%, Often 8.9%, Sometimes 17.7%, Never 50.2%, n/a 20%. Then I summed up the “always” and “often” answers. I repeated the same process for other questions, then I calculate the average of them and reported as the percentage.

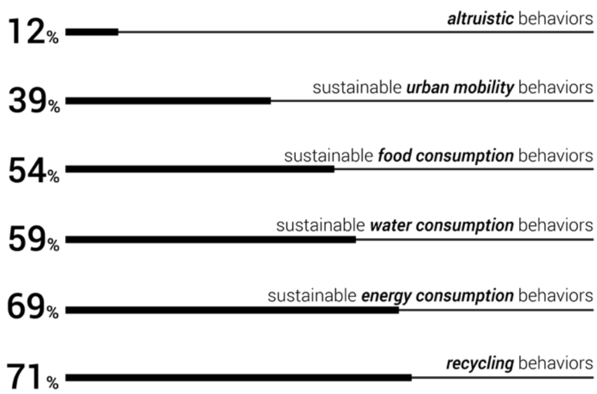

Figure 19: Sustainable behaviors: result of the questionnaire.

Furthermore, many of the questionnaire participants reported that they would purchase and use a computing and smart object, able to help them to modify their urban mobility behaviors. For instance, 36% of participants answered “Absolutely useful, I will try it.”, and 49% answered “I would like to try it, it seems to be useful”. This shows that participants are most interested to purchase a smart object in order to help them to change they urban mobility behaviors than other behaviors. For instance, for energy consumption behaviors 29%, for recycling behaviors 28%, for educational purpose 32%, for healthy food consumption 35% of participants answered “Absolutely useful, I will try it.” (Figure 20)

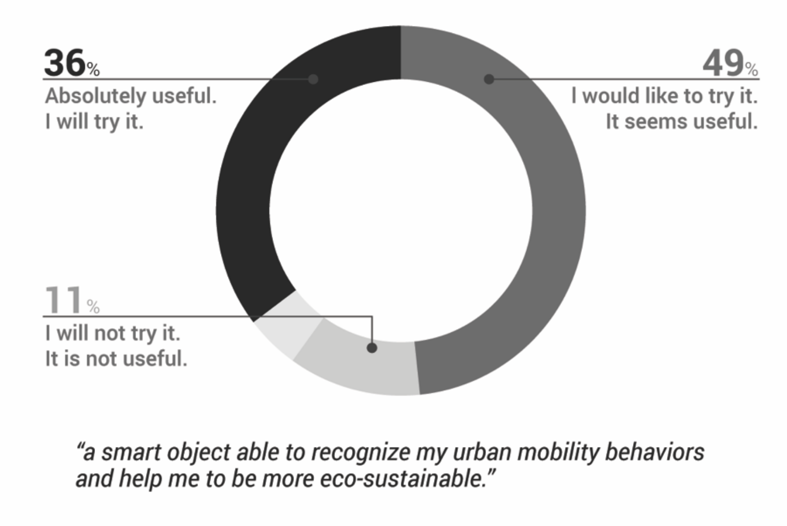

Figure 20: Smart objects for urban mobility behavior.

A design challenge

In my research, and in particular in the stage of ""Concept Situating"" I had to deal with a familiar design challenge and I think it is worth to mention it and reflect on it a little. This challenge was about staying true to what is actually needed to design for, and what the design brief is asking for. As the main area of my research, and what was included in initial brief that I have received from funder company was designing IoT devices for behavior change in Smart Home, so it seems obvious that we need to pick a domestic behavior as the target for my project, for instance, energy consumption, water consumption, etc. After I studied the regional database and also according to the result of the questionnaire we conducted, the urban mobility behavior resulted as the one we need to work on. As the city of Turin, increasingly needs to foster sustainable urban mobility behaviors in order to reduce the negative environmental impacts and its overall pollution, which is due to the excessive use of cars in the city. So, I had to consider home environment as a domestic and indoor setting, for fostering sustainable urban mobility behaviors as a metropolitan and outdoor behavior and activity. At this point considering home environment as the setting in design brief, I had to choose between these two options: 1) ignoring the urban mobility behavior, as it is not an indoor and domestic behavior and picking another sustainable behavior, which is related to the domestic environment, for example energy consumption, 2) design for what is necessary and crucial, and situate it within the context in design brief. I chose the second one.

So, I started to study the home, its places, human activities and objects that are situated within, in order to find a suitable place and object in domestic environment for fostering urban mobility behaviors.

4.2 Place

The concept of "place" has been long the central concern in geography, but it is only since 1970s that it has been conceptualize as a particular location that has acquired a set of meanings and attachments. As Cresswell states, the geography is about places, but the commonsense use of this word contains it conceptual and complex character (Cresswell 2009). A place is where we encounter a particular combination of materiality, meaning, and practices. The political geographer John Agnew has outlined three fundamental aspects of place as a "meaningful location": location, locale and sense of place (Agnew 1987). In his definition, location refers to the 'where' of the place, its spatial coordination –its latitude and longitude. Locale refers to its material configuration and settings, its tangible and visible aspects –it is how a place looks like, about its concrete forms. The sense of the place, further is about the human 'relationships' with the place:

> "… By sense of place Agnew means the subjective and emotional attachment people have to place". (Cresswell 2015).

Cresswell further describes, that the sense of place is often associated to belonging, which is actually what make distinction between two concepts of space and place. A space is a more abstract concept, it is free and open, because it is about geometries and volumes, a place instead is about security stability and belonging. (Cresswell 2015; Tuan 1977) Place is also a way of knowing and seeing the world. A way through which we can see connections and relationships between people, things and places.

The concept of place has seen a growing interest in HCI, especially since the ideas of Ambient Intelligent, Smart Home, Smart Environments have emerged. The emergence of personal computers brought computers to the new environments such as the home environment and it defined new usages for information technologies (e.g. Venkatesh 1996). This was early on envisioned by Mark Weiser at Xerox Parc, who also introducing the idea of Ubiquitous Computing (Weiser 1991). Since then many researchers have adopted his vision for designing new computer-enhanced and interactive artifacts and environments (Dalton et al., 2016). Some researchers have even suggested to join the areas of interaction design and architecture as to use interaction design methods and explore interactivity at the scale of architecture (e.g. Wiberg, 2015 and Dalton, et al., 2016). It helps also to fully understand the relation between interactive objects, not only with humans, but also with the places we design and inhabit. Many researchers have further investigated how the flows and patterns of activities in a space can guide the design of interactions with smart objects. In particular, the notion of *place* is used when spaces frame interactions through cultural values and behavioral expectations (Harrisson and Dourish 1996).

Home

The most familiar example of a place is home. Home as a "place" is an architectural space, filled with its particular flows of activities, its objects that belong to that space and people who dwell within. Home is often used as an example of place where people have attachments and sense of belonging. As Tuan argues, making of places, regardless of its scale, has been always seen as making a sort of homeliness (Cresswell 2015). Home as Seamon argues, is an intimate place where people can have a degree of control over a limited space (Seamon 1979).

Home Computing

Smart Home has been defined by various academic and commercial research as a home where household appliances and services are enhanced by Internet connectivity (e.g. Harper, 2003). The growth of the Internet connectivity brought an increasing interest of using computer technologies in the home environment with the aim of meeting people's needs, such as staying healthy, organize family life and the feeling of security and peace of mind. This target, the domestic environment by producers of information and communication technology as the site of the consumption of such technological artifacts (Venkatesh 1996; Ericsson Consumer Lab 2015). However, designing for the domestic environment requires a deeper understanding of the nature of this environment and the relation between technical and social aspects. Applying the CSCW studies of organizational life, from every day collaborative activity to the domestic environment has been the purpose of many researches (e.g. Bentley et al. 1992; Button and Sharrock 1994; Luff and Health 1998; Pycock and Bowers 1996; Rouncefield et. al. 1994).

General studies of the home as a site for computing technology consideration has been the purpose of the many scientific researches, which mostly concerned the concept of time management and savings (e.g. Morgan et. al, 1996, Robinson et. al. 1972, Vanek 1978) and the impact on women's roles in the household (e.g. Strober and Weinberg 1980, Davis and Rigaux 1974). Venkatesh investigated the relationship between households and technology for the first time and the interactions between the technological and social arrangements of the home. As far as the adoption of a new technology for home is concerned, the important role of the internal ecologies and value systems, comes into play. O'Brien (1999) considers home environment as a dynamic system and outlines the particular manner in which it creates the balance between exogenous (i.e., external to the household) and endogenous (i.e., internal to the household) forces, differentiates households from other social institutions.

Computers have been entered in domestic technological environment mostly for performing domestic activities in a more efficient way and at a lower cost and creating new realities and capabilities. (promoting behavior change). The five dimensions of household technologies has been discussed in Venkatesh's model (1985), which vary from instrumental vs. expressive (Parson 1951), task vs. pleasure oriented, passive vs. active, uni-functional vs. multifunctional and low social impact vs. high social impact. The social impact of the technology, is defined as the potentiality of technology to alter the existing modes of life; activities, habits and behaviors not only within the household but also in a broaden social context where the dimension of the impact is proportional with the dimension of the change.

The new technologies may create new life patterns and habits, change or preserve the existing ones. Kirsh and Venkatesh (2006) found out that everyday routine activities and the set of rights and obligations in the home are so closely interwove with technology, thus the technology not only fits within routine of home life but also can change and modify them, which can also generate the patterns of activities.

The pattern-based approach informing the design of future technologies for domestic environment (Crabtree 2002) is originally adopted from the works of Christopher Alexander (1977, 1979). The work of Crabtree represents another contribution to the understanding of social circumstances of technology usage in the domestic environment, by exploiting the basic principles of pattern languages and using the descriptive patterns for the first time to convey an understanding of the social organization of domestic environment and the technology usage within it. According to the pattern framework proposed by Crabtree (2002) the patterns of actions and interactions are tied to the particular context, for instance taking the shower is tied to the bathroom, breakfast to the kitchen.

As Alexander (1977) puts, all recognizable patterns are anchored in space, thus we cannot imagine any pattern without imagining a place where it is happening. And also, the patterns of action can generate the concept of the place (the place within which we take shower is bathroom). The primary objective of pattern analysis is to identify the patterns of relationships between actions and the material arrangements of place: between a person entering a building and the physical entrance, between cooking and the physical configuration of the kitchen and etc. (Alexander 1979). Crabtree interprets the two main categories of “larger” patterns and “smaller” patterns defined in Alexander’s definition of patterns. He outlines that larger patterns may be defined as the primary patterns that determine the place, (e.g. making breakfast in kitchen), while smaller patterns may be component patterns that make up a primary pattern (e.g. getting food from refrigerator, cleaning the table, etc.). According to the adapted version of Alexander’s pattern framework, patterns of relationships reveal patterns of technology usage and the notion of material arrangements of place may be extended to include technologies and this framework can be useful for the future designers of interactive systems.

Technical and social challenges of the Smart Home proposed by Edwards and Grinter (2001) cover the problems regarding the ways inhabitants expect the smart home should be; technical issues regarding interoperability, and manageability and reliability; social concerns of adoption of domestic technologies and design issues that arise from considering just how smart and interactive a smart home should be. They also outline the fact that an individual usually does not own the domestic technologies (TV, telephone, etc.) thus the domestic technologies are usually shared among different family members

(Venkatesh 1996; Edwards & Grinter, 2001). However, the technology could create the spaces of "ownership" within the domestic environment. (e.g. the temporary ownership of a certain place in front of the TV) O'Brien (1999).

In-between places

Home as a place cannot be isolated, rather it should be considered as a place in relationship with other places, such as city. So, as my research has urban mobility behavior as the target behavior, these relationships between home places and city places become even more crucial. For the purpose of studying these relationships, first I sought to study different places in home environment – including understanding what objects people usually use in those places and also what activities people often carry out there. Then according to the character of those places I labeled them in three categories of 1) intimate, 2) family/social and 3) in-between places. Whereas in-between places are those areas in home environment, that do not manifest any characteristics of an intimate place nor those of family places. In addition, they are places for transition from inside to outside of the home environment. The concept of transitional spaces has been long the subject across many disciplines, spanning from psychology, to organizational and architectural studies. For instance, in psychology, a transitional space is where an infant grows thank to the transitional objects and transitional phenomena (Winnicott 1953). In organizational and architectural studies, transitional spaces are those spaces for transition from one space to the other. Spaces can be natural/artificial and/or indoor/outdoor. Often in architecture, transitional spaces are also referred to those spaces that connect different indoor spaces, for instance there often exists a transitional space between kitchen and bedroom. In urban studies, a transitional space or sometime called as a non-place, is an architectural space, that people transit through, they do not stop, do not engage and familiarize, for instance a train station or airport are non-places. However, it has been argued that non-places are the results of our highly-mobilized world. (Cresswell 2009; Auge 1995)

Figure 21: In-between places.

Domestic environment is considered as a socially organized space within which, different activities may occur in collaboration with or without other members. To this aim, a framework is proposed for the home living that decomposes the domestic environment into three main areas of intimate, family/social and in-between places (Figure 21 and 22). The intimate spaces are defined as the spaces of intimacy and for being alone. The social spaces are the spaces within which, the major interaction and collaboration occurs among family members and friends and finally the in-between spaces are defined as the spaces between home-environment and the city-environment.

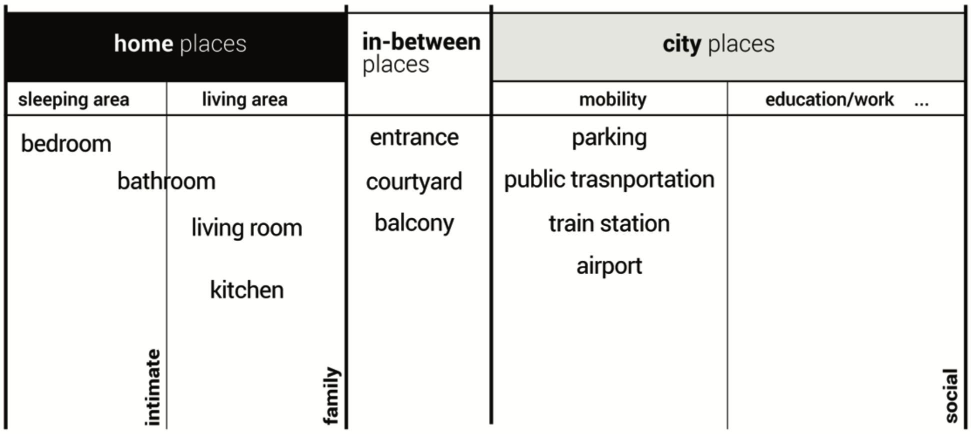

Figure 22: Home-city places framework.

When we talk about home and city, we automatically create a sharp spatial and meaning distinction between them. Home is where we live our private lives and city is a place for our social and professional lives. In this framework, I sought to put more emphasis on the *in-between* spaces, which are located within home-environment spatially, but represent as the interface between home and the city spaces, as a transitional space but still within home.

The assumption is that the in-between space due to its particular characteristics, location and configuration could be considered as a connector between home and city spaces and so might become suitable space for designing interactive artifacts that support reflection about urban mobility behaviors.

Places for reflection: Activities, People, Artifacts

Having selected *in-between* places as a suitable place for supporting reflection on urban mobility behavior in home environment, next step is to select an in-between place, and design for it. But I would first go through 1) a brief related work section on supporting reflection with interactive technologies in home environment and 2) relationships between a place and its artifacts, and the activities that people often carry out.

In designing smart homes, attention is often paid to the user experience and to the ways in which those environments can support the inhabitants' daily activities. Furthermore, many smart objects aim to not only support but also capture awareness of and evoke reflections about user activities in domestic environments. For example, reflecting about activities that require reductions in energy or water consumption, or reflecting about food consumption in order to foster behavior changes toward healthier food choices. Although the purposes in those examples may differ, they share the same principle: Reflection can help people make better choices and change behaviors.

In this regard, Lars Hallnäs and Johan Redström's slow technology (2001) is an approach that emphasizes the role of technology to foster moments of reflection—instead of efficiency in performance—in domestic environments. More recently, the HCI community has provided many experimental and speculative examples of smart devices that can support reflection in the home. For instance, *Data Souvenirs,* by Aipperspach et al. (2010), is inspired by environmental psychology and emphasizes the important role of the physicality and familiarity of objects that support reflection. *Lover's box,* by Thieme et al. (2011), is another example of such a physical, everyday artifact, and aims to evoke reflection on romantic relationships between couples.

Bowen and Petrelli (2011) used the concept of autobiographical memories and "digital mementos" as tools to help people reflect on their experiences in the home. In particular, "critical artifacts", products of a critical design process, were used in a design study in order to enable users to envision ways of using technology in the context of personal experiences.

Considering reflection as a driver of behavioral change, a number of projects have investigated the role of physical artifacts in achieving such change. For instance, *Keymoment* (Laschke et al. 2015) is a key hook with the purpose of fostering more healthy and sustainable urban mobility behavior, by encouraging its users to take their bike key instead of their car key. In particular, the design of the key hook helps users to remember and reflect on the choice of transportation in a pleasant way, at the moment of leaving home. A similar idea of using a key hook as an artifact for reflection on urban mobility behavior has been conceptualized by Ghajargar et. al (2015), who have inspired by environmental psychology and the theory of our implicit connection with nature (Schultz et al 2004). Mckinnon's "Domestic Reflections, Electric Reflections" (2016) which focuses on the everyday mundanity and critical design as an approach for designing interactive and every-day objects for sustainable behavior change. "The Eco-Feedback Technology" is another concept, using digital and physical artifacts, mostly ambient displays to capture awareness about user behaviors (Froehlich, Fidlater and Landay, 2010). Feng Gao's "Design for Reflection on Health Behavior Change" (2012), takes an instance on alternative ways to persuasion-based systems for behavior change specially in dietary context.

Reveal-it is another example of using large digital displays for empowering people, by evoking thoughts on energy consumption at both individual and collective levels (Valkanova et al. 2013). Social interactions also seem to play a relevant role in the reflection process, because they require talking with other people about the experiences, helping to recall memories. For example, interactive systems for behavior change increasingly "focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action" (Ploderer et al. 2014). Reno and Poole's "It Matters If My Friends Stop Smoking" (2016) which also focus on the role of social support for behavior change.

Further reflection as a distributed cognitive process, is not only an individual and internal process, but it also requires external stimuli: objects, other people, activities, and the environment (e.g. Salomon 1992; Rogers 1996). Furthermore, in HCI, *reflection* refers to the action of thinking about the information provided by smart objects in order to capture awareness about an action and its consequences. Accordingly, reflection can become a valuable concept in the design of everyday smart objects embedded in place (Ghajargar & Wiberg 2018).

People not only think with objects, but they also often engage in an activity with an object, so *reflection about an activity* is connected to the smart object, the activity, and the place (Turkle 2011; Whittaker, Terveen and Nardi 2000). Consequently, designing for reflection about an activity requires consideration of the relations among those factors, which deal with the social, aesthetic, and technical interactions in a given environment (Harrisson and Dourish 1996).

The components of a place include objects (smart, digitally enabled, or not), people, user activities, and the architectural structure of the space itself. However, in order to have a systematic approach and a clear idea about the outcome of design, we may focus on one component at time and then consider the relationships around it. So, I will start with the place, since it physically contains the other components, and then illustrate the relations within it. I will explore the three main relations, namely: 1) place-activity 2) place-artifact and 3) place-people relations. (Figure 23)

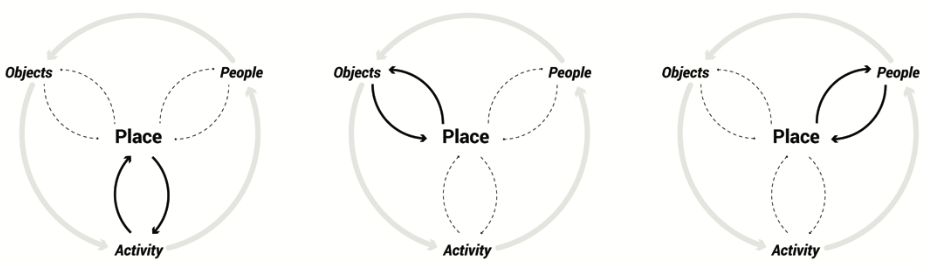

Figure 23. The three main components and their relationships.

Place – human activity relations

Home is a private architectural space where people live their private lives, have personal relationships, and perform activities that are often distinct from those in their public or professional lives. Thus, the architectural space definition and meaning are closely related to the activities the user usually does in that space. For instance, a *kitchen* is defined as a place where people *make food*. Accordingly, there are tasks related to that place, such as cooking, boiling water, cutting vegetables, and so on. Those are activities that by definition occur in that specific place. Other examples are, for instance, *sleeping and waking up* in a *bedroom* or *taking a shower* in a *bathroom*. Thus, for example in designing for *reflection about the activity* of *taking a shower*, the *bathroom* is the right place for evoking reflections about that activity.

Thinking about mobility behavior is the activity in in-between places. Most of the participants have expressed that they think about the urban mobility activities in the home entrance area, which is an in-between place. Other external activities and events decided or thought about in home entrance, are for instance checking the weather, thinking about the daily activities, such as picking up children from school, going to the gym, etc.

Place – computing artifact relations

According to the definition and meaning of the place, people engage in tasks in relation to objects, which are generally presented in that specific space. Considering a kitchen as a place, we find pans and an oven; in a bedroom, we find a bed; and so on. So, for designing a smart artifact for reflection in a specific place, it is appropriate to choose among the artifacts that are already existed.

Among the artifacts often presented in an in-between place, lamp has been chosen as the artifact able to evoke thoughts on urban mobility behaviors.

Place – people relations

Some places are for a specific person. For instance, when we call a specific place in our home "my room," this actually means that place has been configured accordingly to my taste, my daily activities, and my things. When other people interact with that place, they may not fully recognize its whole structure and configuration. Alternatively, there are also spaces that are designed for social interactions, for example the dining area in a home environment, which structures configurations that are not specific to one person.

An in-between place has a transitional characteristic, it is not usually neither an intimate or family/social place, so it can not belong to a person or a group of people.

As a part of this analysis, a participatory session has been also organized with the purpose of 1) understanding the flows of activities in different home spaces; 2) the artifacts that people mostly interact with or use, in order to do such activities; 3) identifying an artifact for the purpose of evoking reflection and thoughts on urban mobility behaviors; 4) identifying an in-between place as a physical context of such artifact.

Participatory session

In April 2015, we have invited 12 participates 4 women, 8 men, among people who had been already answered to the questionnaire about assessing sustainable behaviors. The average age of the participants was 33 years old.

Figure 24: ***Nel Luogo in cui Vivi*** **(The place where you live) workshop.**

The purpose of this session was to understand how many objects on average people use in their homes for what purpose or activity and in which place. As a result, we found out that participants do 71 different activities in a morning of a working day before they go to the work.

These activities are distributed in following places: number of 16 activities are being done in bathroom, 16 activities in kitchen, 12 in bedroom, 10 in salon, 9 in entrance, 4 in closet, 3 in balcony and etc. The average number of activities per person in different places is as follows: bedroom 5, kitchen 5, bathroom 4, salon 3, balcony 2, entrance 2, closet 2, courtyard 1.

The session duration was about two hours and we have decided to conduct it in late afternoon (at 5 pm.), so people could participate after work.

Designing the generative tool

Generative tools are supporters for the idea generations, in co-design or participatory sessions. As Sanders put, the landscape of generative tools designed for co-designing with people, is predominantly visual. A number of physical and visual components are put in a generative toolkit and participants can choose from them, and work and build their ideas or express their thoughts through them. A toolkit usually has a background, it could be an image, a table, or guidelines and words. (Sanders 2010)

For this stage of my project I designed and developed a generative toolkit. The generative paper based toolkit has three main components (Figure 25). The component number **one**, compromised of appropriate areas for each space of home environment. We have selected four main areas that are usually present in a domestic environment, also according to the results of the questionnaire: 1) Bedroom; 2) Bathroom; 3) Kitchen and 4) Home Entrance. Then we provided also two free spaces for participants to add additional names of home spaces.

For each dedicated area, we asked participants to mention and write down the activities that they usually carry out in that space. Also, participants have been asked to mention if there are other people involved in the activity. In these areas, each participant writes the name of activity beside a number. The next area is dedicated for mentioning the objects they use for that activity, providing also the number of the activity they are associated with. In this area, participants need to use the component number **two** of the generative toolkit, writing the name of the object, cut it and then paste it in the dedicated area. This component of the toolkit, help participants to divide objects, in computing and non-computing, mobile and fixed. In blue areas of the component number one, participants need to write down the urban activities that they manage, think about or organize in that specific place of home, using the component number **three**. (Figure 25 and Figure 26)

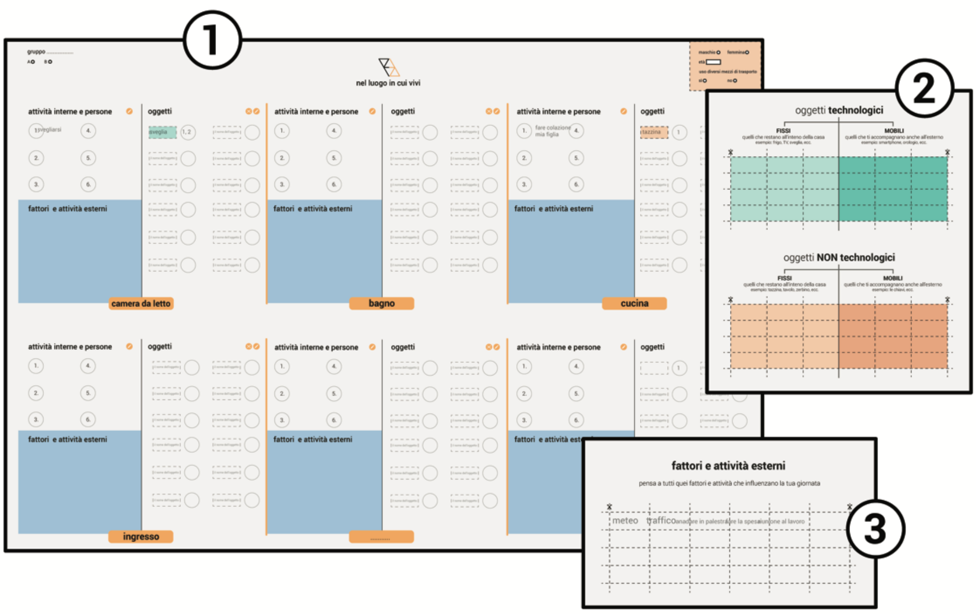

Figure 25: Generative toolkit.

The participatory session has been conducted with 12 participants selected from respondents of the questionnaire. An invitation has been sent to them about one month prior to the workshop date. The average age of the participants is 33 years old, among them 33% female and 66% male. We have asked from the participants if they use different means of transportation through a brief questionnaire and 92% of the participants reported to have a multimodal mobility behavior (100% cycling and walking, 84% uses public transport, 67% uses car sharing, 50% uses personal car, 17% uses motorcycle).

Figure 26: Use of the generative toolkit during workshop.

One in-between place, one activity, one object

The transcription and analysis of data obtained from participants show that participants, carry out **71** different activities using **131** different objects in **9** different areas of the home environment. In this stage, in order to converge the design process towards a place and an activity to design an object for, I attempted to start with the choice of the place. As this has been discussed earlier, the kind of places in home environment, which have been assumed to be suitable for fostering sustainable urban mobility behavior, are in-between places. Among the in-between places that we have analyzed during this workshop, the home entrance has been the one with more activities associated with, more objects and also more thoughts about urban activities. So, the home entrance has been selected as an in-between place. This suggestion is also based on the framework presented earlier in this dissertation, which consider the home entrance as the most suitable area in home, where we transit from inside to the outside of the private space of the home. Having picked the place,

I went through the analysis of the activities carried out there. In total, 6 activities in home entrance (Putting on shoes = 2 times, Closing the door = 2 times, Accompanying family = 1 time, getting ready = 5 times, Checking the weather = 1 time, turn on/off light = 3 times) have been identified. The next step was to pick up an object in that place. The number of 12 different objects (Shoes = 3 times, Keys = 4 times, Umbrella = 1 time, Smartphone = 2 times, Drawer = 1 time, Wardrobe = 1, Shoe rack = 1 time, Lamp = 3 time, Cloth hooks =

1 time, Backpack = 2 time, Hat = 1 time, Helmet = 1 time, Socks = 1 time, Door = 1 time) have been identified in home entrance. In order to choose the object in relation to the activity I calculated the ratio between the number of times an activity has been indicated from participants and the number of objects linked to that activity. It has been useful for the design process, because it facilitated the choice of just one object. This analysis led to choose the lamp as the object, which is linked to just one activity. (ratio of No. activities/No. related objects = 1.) (Table 2)

So, in summary, the concept has been situated within the home entrance in home environment. A lamp has been chosen as an everyday object used in home environment.

In the next chapter I will describe the process of designing and prototyping the lamp named *Sóle.*[5]

[5] *Sóle* is an Italian word and it means sun. It is the symbol of clarity and evidence and it is often referred in literature as the source of wisdom and sapience in Dante's writings. (Treccani: http://www.treccani.it/vocabolario/sole/)

Table 2: Activities and objects in home entrance.

Activities	**No.**	**Objects**	**No.**
Putting on Shoes	2	Shoes	3
		Shoe rack	1
		Socks	1
Closing the Door	2	Door	1
		Keys	4
Accompanying	1	--	--
Getting ready	5	Backpack/Purse	2
		Hat	1
		Helmet	1
		Cloth hooks	1
		Wardrobe	1
		Drawer	1
Checking the Weather	1	Smartphone Apps	1
Lighting On/Off	3	Lamp	3

Chapter Four: Concept Situating

Chapter 5

Concept Appropriating

In this chapter, I will describe the actual process of designing and prototyping of a smart lamp, named *Sóle* for home environment. As I have described in previous chapter, the concept has been situated in the entrance of home environment, and for urban mobility behaviors. So, the *Sóle* as an everyday object is a *Tool for Reflection*, but what kind of lamp it is? What physical forms it should have? How characteristics of a *Tool for Reflection* can be translated into a its forms and behaviors? In following sections I will seek to answer these questions.

5.1 The *Sóle*

Sóle is a lamp for home environment, specifically designed for the home entrance. It is connected to a mobile application, through which receives the data previously collected and elaborated, regarding means of transportation used, the kind and the duration of usage. Then *Sóle* provides feedbacks to the users, about urban mobility behaviors. The mobile application as it is shown in the figure 27 provides two main feedbacks regarding the user's urban mobility behavior in its summary page *(statistiche)*, one is related to the user as an individual, and the other one is related to user's community urban mobility behaviors. The size of the circles shown in the figure 27, is related to the scale of user's sustainable urban mobility behaviors.

5.2 Designing the *Sóle*

In designing the *Sóle*, I considered three common types of lamps used in home environment: wall lamps, table lamps and floor lamps. I studied their components, ergonomics, functionalities and dimensions. Since the beginning of designing activity, possible forms and structures that can be adapted to either a table or floor lamp were desirable and encouraged. So, I started sketching some ideas for these three types of lamp (Figure 28).

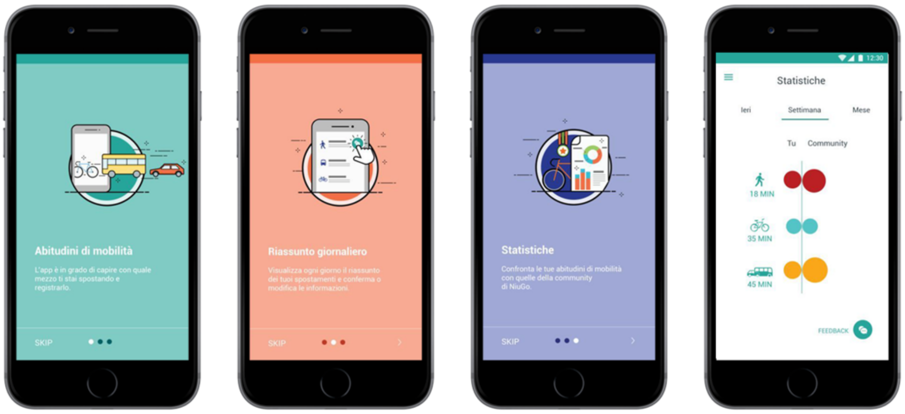

Figure 27: Mobile application (Courtesy of TIM Swarm JOL: Open Agorà project).

Form giving: sketching

Krippendroff, emphasizes on the fundamental role of form giving in design process. In his seminal work Semantic Turn, he even defines the Industrial Design as *"the creative activity that lends form and meaning to industrially manufactured objects, both for mass and limited production"*. Further he affirms that form and meaning are, indeed, intrinsically correlated: *"Something must have form to be seen but must make sense to be understood and used"* (Krippendorff 2004).

So, for giving form to *Sóle,* I started with sketching some alternative forms for the *Sóle*'s structure. Although in the structure of this dissertation I write about Sketching step before talking about the characters and behaviors of *Sóle*'s final design, it is worth noting that these two steps were actually intertwined and one step fed the other. During sketching phase, I tried to understand not only how the forms that I am giving to the *Sóle* can support the characters of the *Tool for Reflection* concept, (which has been defined in the chapter 3) but also how those characters can be translated into the physical forms. So, the activity of sketching supported the *Sóle*'s form-giving considering the characters of the *Tool for Reflection* (Figure 29).

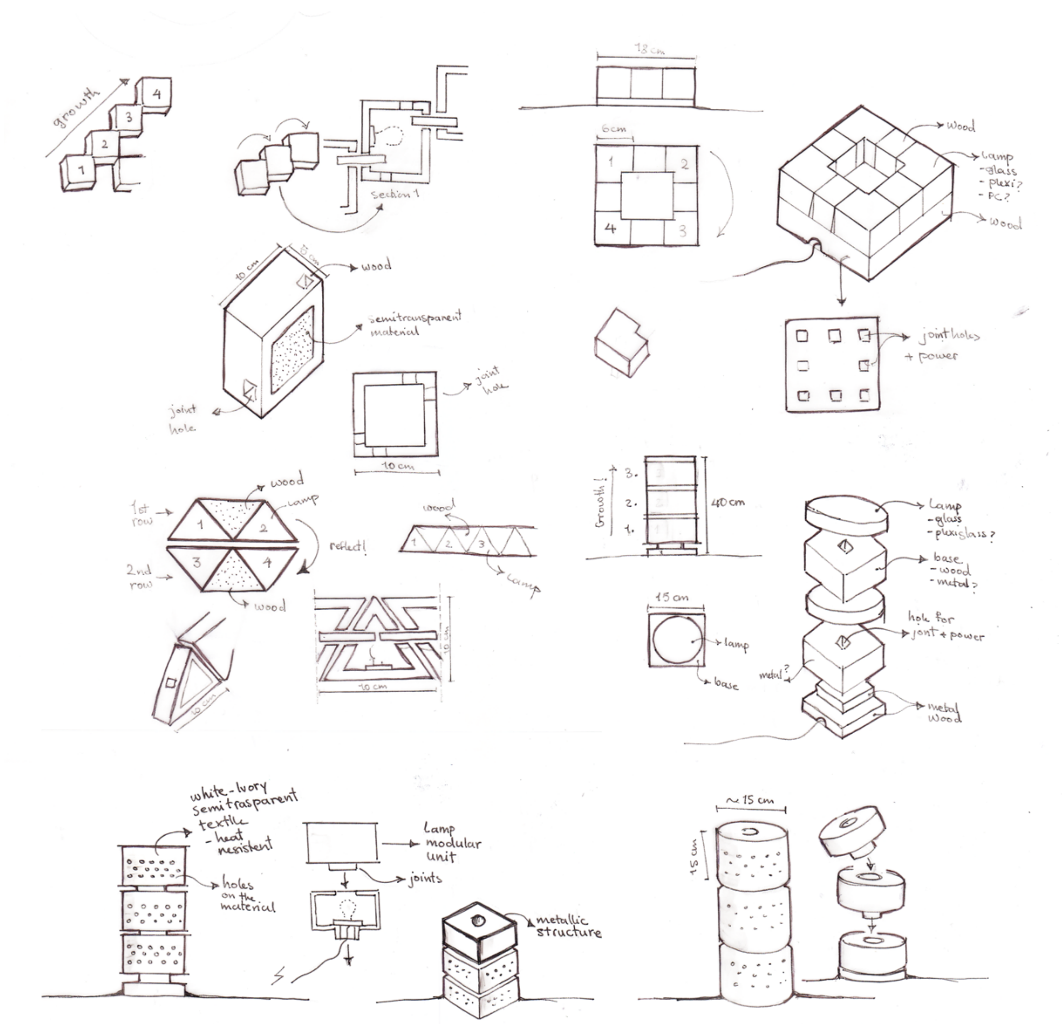

Figure 28: Early sketches for *Sóle.*

In sketching alternative forms for *Sóle,* I considered a structure composed of modular units. Among alternative forms and models, a table lamp model has been chosen which is composed of three modules initially. This structure enables the lamp to become also a floor lamp, by providing user the possibility of adding more units. (Figure 29: bottom-right sketch)

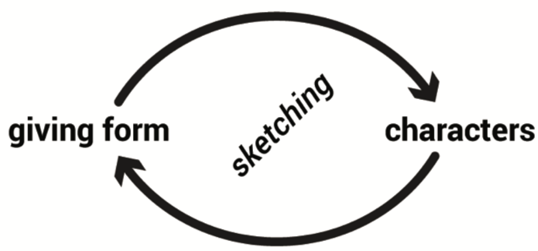

Figure 29: Sketching.

Sóle final design

Once the model and forms have been chosen, I sought to further consider how the structure expresses and translates the characteristics of a *Tool for Reflection*: being ***Reflectional, Experiential, Communicative and Deliberative.*** Although these characteristics coexist and are in relations with each other in a way that one characteristic enables another one, I will go through them briefly and will present how I applied and translated them to a simple ever day object: a lamp.

Reflectional is the capacity of evoking thoughts and reflections in user through providing peculiar tangible and visible feedbacks. It is related not only to the physical forms of artifact but also to the interactional and temporal forms of the artifact (e.g. Ishii and Ullmer 1997, Wiberg and Robles 2014, Vallgårda and Redström 2014). These feedbacks, as perceived by user, demonstrate radical or incremental changes in the *Tool for Reflection* structure, such as changes in form, texture, light and color, results of the *Reflectional* characteristic. In *Sóle* lamp, a *Reflectional* feature is related to the ways lights behave, diffuse and move alongside the structure. So, I designed two different ways that it can provide light-based feedbacks, which user can select among: A) to arise mode, B) to accumulate mode (Figure 30).

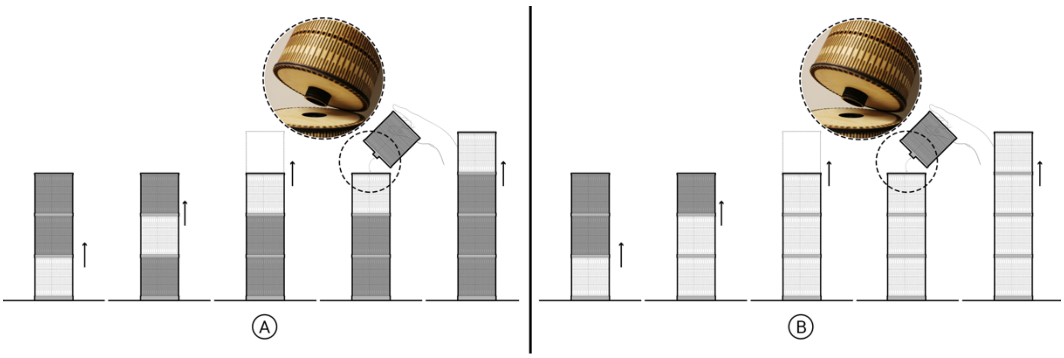

Figure 30: A) To arise mode, B) To accumulate mode.

Sóle is also *Communicative* thanks to these light behaviors. In the *to accumulate mode,* more light bulbs will be turned on, if user for instance uses more bicycle, and that results in having increased number of turned on light bulbs. In the *to arise mode*, the light bulbs will turn off in lower units and turn on in the upper units sequentially, which result in raising the position of light alongside of the lamp (Figure 30). The user will have the possibility to choose a light behavior between these two options. The *Sóle* communicates with the user in an abstract, somehow qualitative way. It is also calm and requires little user's attention (Weiser 2009; Bakker and Eggen 2015). However, the numerical values are always accessible through the mobile application that collects and elaborates data.

This could be considered as an alternative way of communication compared to the way traditional ambient displays and eco-feedback technologies communicate with users (changing in color from red to green), even though both share some principles. For example, eco-feedback uses also smart technologies to develop devices for the home environment to provide feedback on individual or group behaviors with the purpose of reducing environmental impact (e.g. Froehlich et al. 2010). This qualitative way of communication, thanks also to the white light color, instead of usual red-green light colors, is the *Communicative* character of *Sóle* as a *Tool for Reflection*.

In another version, the user will have also the possibility to use the lamp units separately. In this way, the units can be distributed and placed in different places of home environment, for instance one in home entrance, one in bedroom and one in kitchen. While the first option –assembling units all together in a unique structure– might communicate a more static, direct and immediate message, in a single place, the second option –distributing the units across home places– communicate in a more playful and dynamic way, whereas the playfulness and openness are empowered as two important drivers of reflective thinking.

Physically being engaged and learning with tangible computing artifacts as active partners can also enhance learning and cognitive development (e.g. Price et al. 2003; Rogers and Muller 2006) and this is part of the *Expereintial* character of the *Sóle*. In fact, arguably, this is one of the most important characteristics of a cognitive tool to be suggested since the development of the constructivism theory of learning and cognitive technologies (Piaget 1947; Jonassen 1997). One opportunity to incorporate this property into the physical structure of the artifact is to build it out of physical modular units. So, the modularity of the *Sóle*'s structure helps the user to be engaged more with the artifact and experiment with it, which is another important aspect of the reflection. This also helps the user to be engaged to her/his behavior and shape and build a structure for the behavior to grow and improve. The *Sóle*'s structure also provides the opportunity to add more units for transporting the light from bottom to top units (Figure 30).

In the next section I will provide, some technical drawings of the *Sóle* lamp before getting ready for prototyping. In the orthographic views of *Sóle,* a front view, a side section view and a top view have been illustrated in order to provide details about shapes, dimensions, composition, joints and electronics (Figure 31).

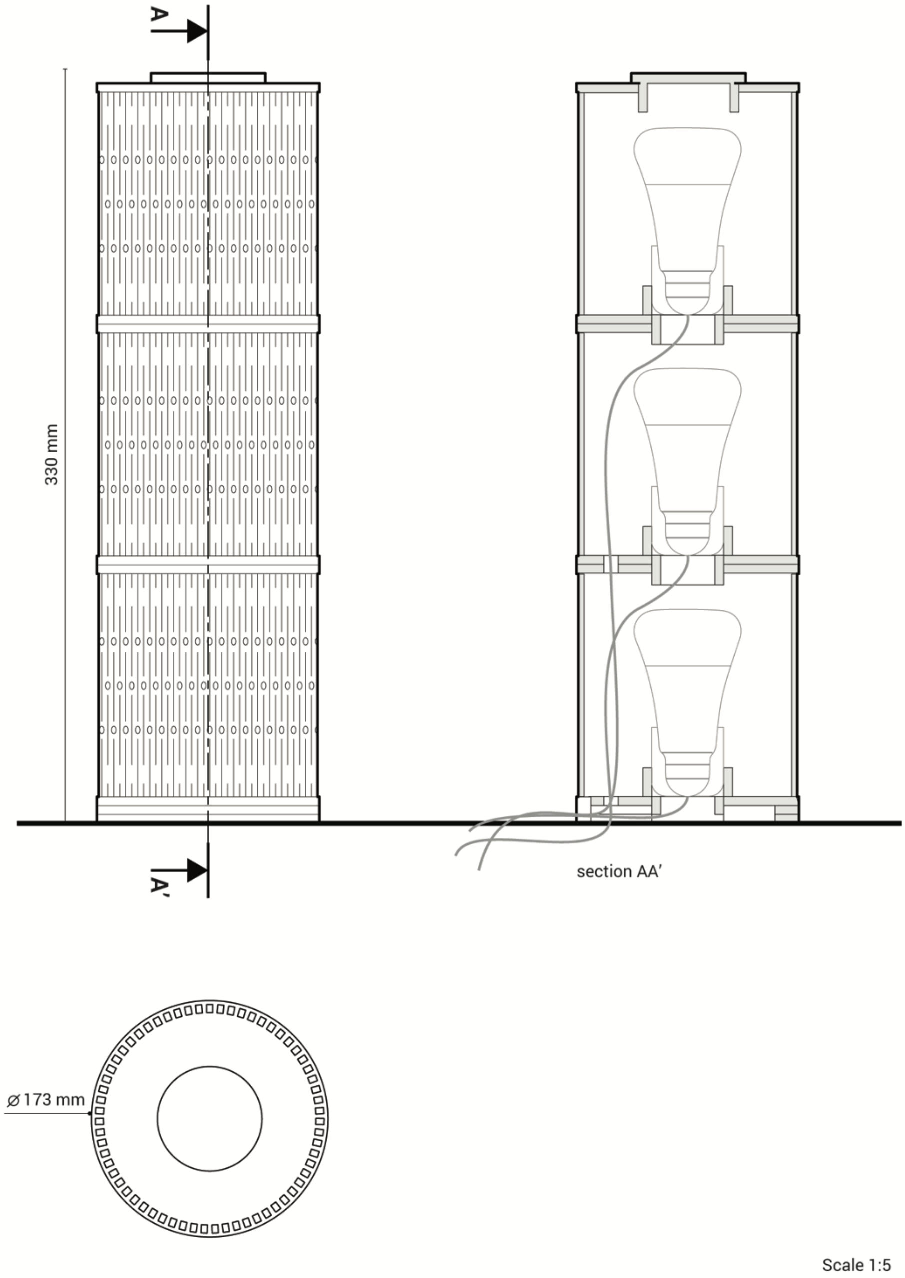

Figure 31: Orthographic views of *Sóle* prototype.[6]

[6] The wires shown in the figure, will be replaced with cordless electrical connection, for the final version of the product.

5.3 Prototyping the *Sóle*

The components, materials and building techniques have been selected according to the design requirements and also available resources. For instance, plywood has been chosen as the material for building the prototype, as this material was largely available from local producers in northern Sweden and also used for cutting with laser cutter – I made the prototype while I was working as a visiting PhD student at Umeå University. I used laser cutter for cutting the pieces of *Sóle* out of plywood, as this machine enables building the prototype faster, and also enables using the Kerf bending wood technique for curving and bending the material. This technique gives new properties to material.

Form giving: making tangible

Product design has a long tradition of engagement with and manipulation of materials (Pevsner 1991, Woodham 1997, Raizman 2004). At a certain moment in a design process a transition takes place from an abstract functional description, which reflects no decisions regarding a material form at all, into a first conceptual structure expressing a materialized idea (Ramduny-Ellis et al, 2010). Muller identifies this moment as the beginning of the form-creation phase, 'that starts at the moment that any conceptualization about the material form emerges and ends when a definitive design is established' (Muller, 2001). In this phase, the internal ideas of the designer are externalized, explored interactively and represented tentatively in a visual form using a variety of media (McKim, 1980). The process is not solely concentrated on determining the material conditions for the fulfilment of the function of the product, but is also aimed at establishing the product's desired semantic and aesthetic qualities in relationship to its intended experience, meaning and use. (e.g. Krippendorf 2006, Bergström et al. 2010, Vallgårda 2014).

So, I had started to give form to the *Sòle* in the sketching phase, whereas I went through sketching the possible shapes, forms, compositions, modular structure, joins and materials for of *Sòle*, that can give form to the characters of a *Tool for Reflection* as defined in the chapter "Concept Defining". In this section, accordingly I further studied the forms and materials of *Sòle* and I made it tangible, through building an early model and a prototype.

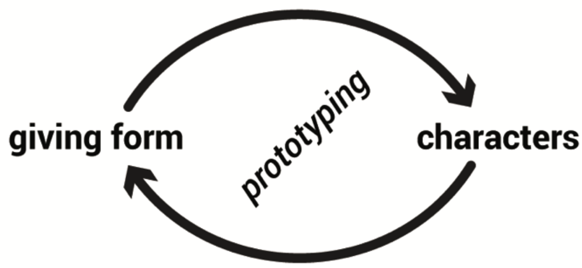

Figure 32: Prototyping.

First, an early model of *Sòle* in 1:2 scale has been built for testing the modular structure and forms (Figure 33). For this early model, I did not use electronics, lamps, cords or any other functional entities, as the purpose of this model was to explore and experiment with the forms, scale, composition, the overall structure, its modularity and joints.

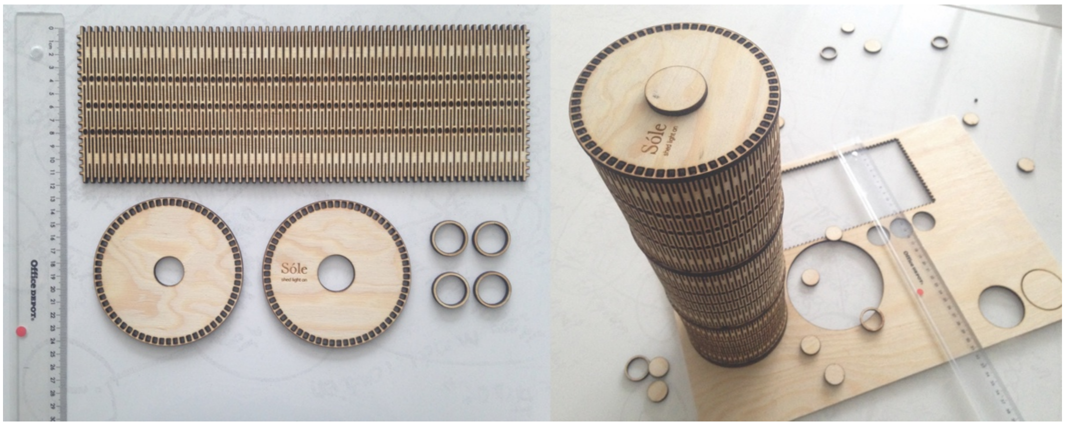

Figure 33: Early model of *Sóle* (Scale 1:2)

The prototype structure is made of 43 pieces in 8 unique shape components (Figure 34). These components have been designed using CAD programs and have been exported in a CAM format and made ready for being cut with laser cutter.

Furthermore, a 1:1 prototype of the *Sòle* has been developed. I used plywood sheets, employed the same kerf bending technique for plywood and used laser-cutter machine. For this prototype, I used three *Philips Hue White Ambiance E27 LED Starter Kit* (Figure 35).

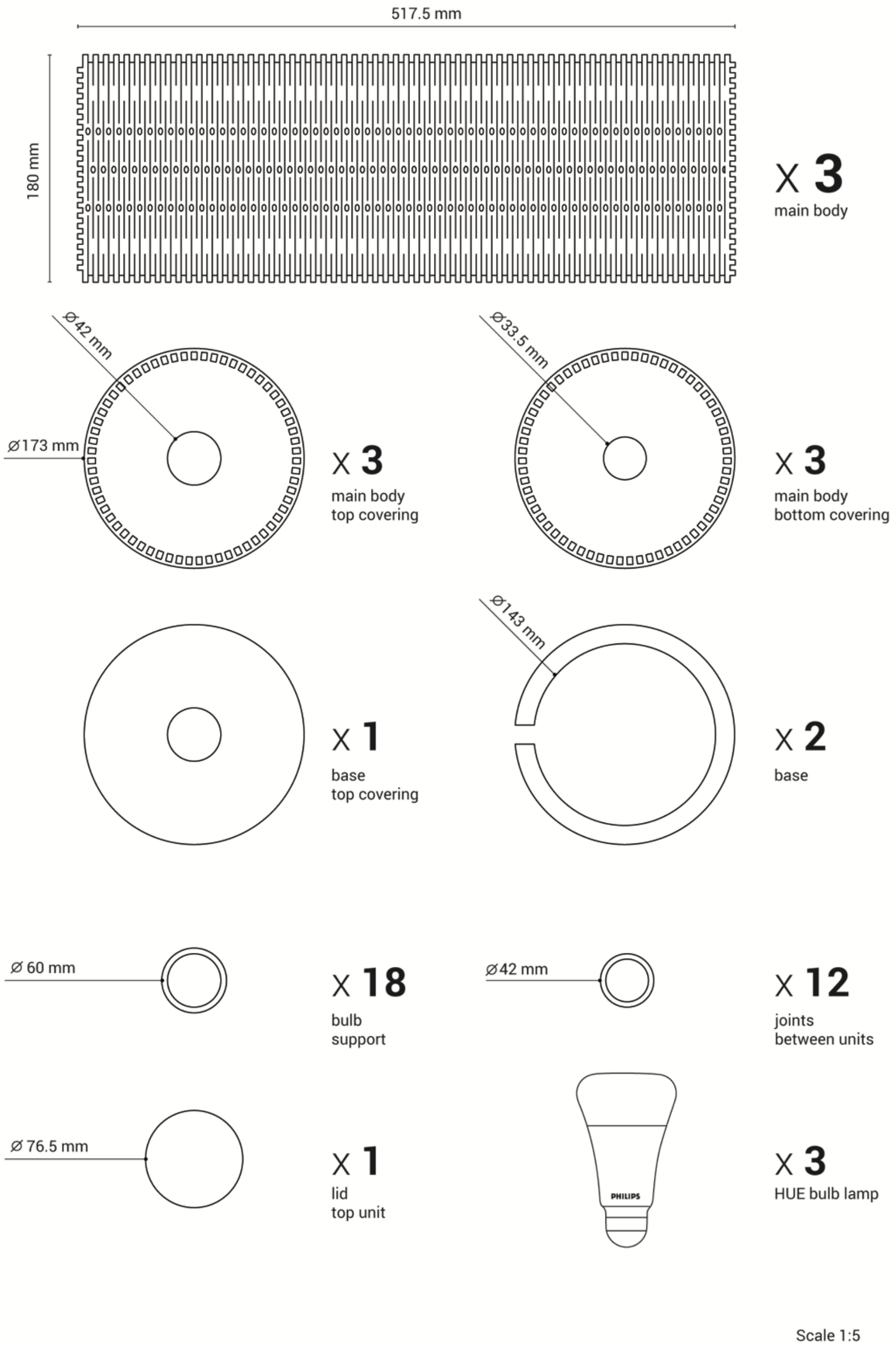

Figure 34: Components of the prototype.

Figure 35: The final version of *Sòle* prototype.

Summary

In an attempt to understand what a *Tool for Reflection* as an everyday object might look like, informing from vast body of knowledge in HCI about reflection, I developed a prototype of a lam named *Sóle*, which has some similarities, but also differences comparing to ambient devices or eco-technologies. It is similar to an ambient device, because it is a lamp, it informs the user by providing visual light-based feedbacks. However, this prototype differs from an ambient device, mainly from two perspectives: 1) *Sóle* is made of modular units and the user can touch and build it physically. This would encourage the user to participate and be an active part of the light behavior, which reflects his/her behaviors. The *Sóle*'s structure can also grow by adding extra units on top of it, which emphasizes even more on the design sensibility towards user's participation in building his/her behavior; 2) changes in light behaviors that occur according to changes in user's habits, are designed in a way that show improvements and the quality. The light colors are natural white, and they do not change colors –e.g. red or green, the common light colors used in ambient devices– they just change the position from bottom of the lamp to the top and vice versa. The physical structure of the lamp, allowed to design two types of light behaviors: *to accumulate* mode and *to arise* mode. In the *to accumulate mode,* more light bulbs will be turned on as a result of a more sustainable urban mobility behavior and that finishes in increased number of light bulbs on. In the *to arise mode*, the light bulbs will turn off in lower units and turn on in the upper units sequentially, which shows visually a raise of the position of light alongside of the lamp structure (Figure 36 and Figure 37).

This prototype served for two purposes: 1) to show an attempt about how a simple everyday object can become a *Tool for Reflection*, by implementing the characters that have been defined previously, 2) to support for iteration as a tool, from practice to the theory, which is the subject of next chapter.

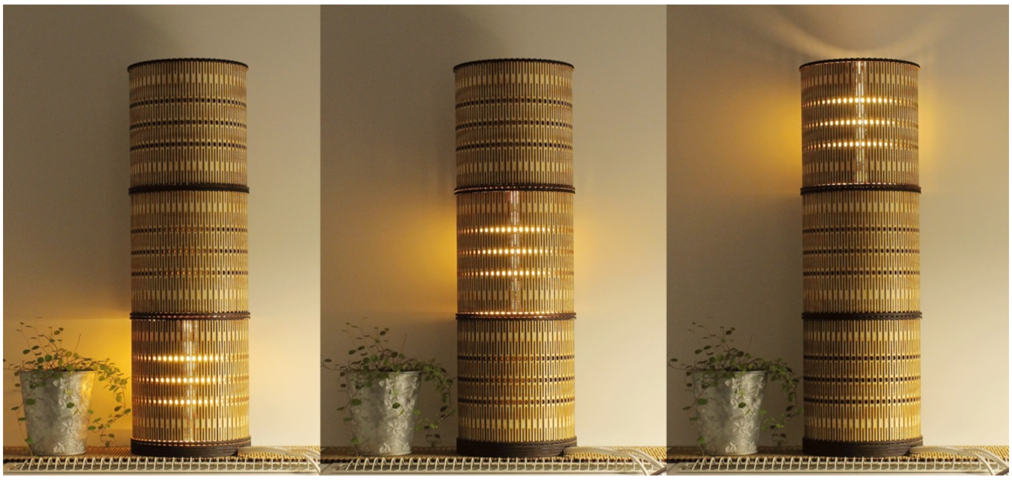

Figure 36: To arise mode.

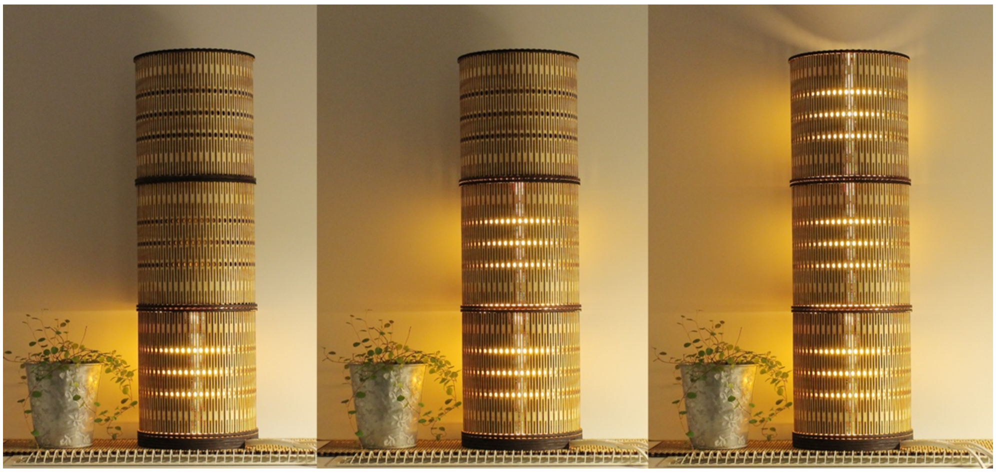

Figure 37: To accumulate mode.

Chapter Five: Concept Appropriating

Chapter 6

Constructing Theories

This is a divergent phase, during which I went through a different analysis of the interactions with the lamp prototype. In this step, I shifted our approach, from the study of the physical and interactional properties of the artifact to a study of relationships that it makes with the user, place and other artifacts. So, in this chapter a relational approach to designing and developing interactive artifacts, in particular, for designing interactive artifacts for reflection has been suggested.

6.1 From characters to relationships

Throughout this dissertation – from defining the characteristics of *Tool for Reflection* to building the *Sóle* prototype, and defining its characteristics and behaviors – the main focus was put on the artifact itself, its physical and interactional characteristics. In this chapter, this approach has been changed and the focus mostly put on the understanding of the relationships between different components of a computing, smart and connected system. Accordingly, I experimented the construction of theories from analysis of the prototype and the main contribution of this chapter is a theoretical model.

In designing interactive artifacts and systems it is increasingly required to understand the interaction and relationships between components –artifacts, places and people. Furthermore, if reflection is relational, and if we set out to design smart artifacts that support reflection, we need a modeling technique that enables us to study those relationships. One that goes beyond the study of “interaction” between computing artifacts and people and considers, instead, the “relationships” as the purpose for design. As Alex Taylor’s After Interaction, highlights, interaction as a concept contributes to separation rather than connections and relationships (Taylor 2015). Since the concept of interaction deliberately makes a clear division between people, computing artifacts and environments, it cannot be suitable for studying the systems of computing artifacts such as the Internet of Things.

There is a need to developing a new approach that views computing artifacts in relation to their user, to their physical and cultural context and not as stand-alone products, focusing on the purpose of that relationship.

So, in designing *Tools for reflection* is not only important to understand and design the characteristics –forms, colors, textures and behaviors– but also their relations with other components of the system. In this chapter I will briefly describe three main relations that interactive and computing artifacts build with their users and then I will draw a new model called *"make me think"*, using an early prototype of *Sóle* as a *Tool for Reflection*.

Accordingly, first some main and existing relationships with computing and IoT artifacts and systems have been analyzed and modelled: namely the *augment me*, the *comply with me* and the *engage me*. Then, building upon those models and through an analysis of the *Sóle* prototype, its physical structure and its light behaviors, I made a model for relationship between a *Tool for Reflection* and user called *make me think* relationship.

"Augment me" relationship

One of the oldest relationships that users have formed with computers is the one that I refer to as the *augment me* relationship. In this kind of relationship, the user and the computing artifact exist in an equal and balanced collaboration. The most important characteristics of the *augment me* relationship are 1) balanced collaboration between user and the artifact, 2) there is always a specific task to be undertaken in relation to the artifact, and 3) the user has overall control of this relationship – a calculator is usable only when a user turns it on, or in the case of software calculators, when a user opens the application or program. The user knows exactly when a calculator is working or when it is on, and for what particular task it will be used.

If one considers a different situation in which the user and the artifact are not in an equal and collaborative relationship, where they do not actually create a one-to-one conversation with each other in order to carry out a task, and where the artifact is not just controlled by the user but also by other sources of inputs/information to which it is connected, how can we then call this a relationship? This situation is the one we actually face when we seek to understand the nature of the relationship between an IoT artifact and the user.

"Comply with me" Relationship

When computers became faster, ubiquitous, artificially intelligent and also connected to the Internet, they became capable of carrying out more complex tasks, some autonomously. In other words, users were no longer required to participate in some tasks, and could let the computer do the task for them. This could lead to a new kind of relationship between users and computing artifacts, the *comply with me* relationship. In this relationship, the user undertakes a few simple steps prior to running the artifact, such as adjusting and installing the device, and then the device itself carries out the task for the user. In this context, the relationship is focused mostly on the computing artifact and the situation, which includes all the different information and input sources, such as other smart artifacts, both local and remote. Therefore, as we can see, there is no actual and direct relationship with the user in order to carry out a task. The relationship between user and the artifact is formed around the way in which the artifact provides feedback through showing the status of the system. The types of feedback provided to the user can vary. They can be in the form of sound notifications, text messages or graphical representations, which aim to provide real-time information about the status of the system or alert (e.g. the *Nest thermostat* generates the text messages “learning”, “cooling”, “away” or gives graphical representations such as the green leaf when a user is saving energy).

This kind of relationship differs from the *augment me* one in the way the user is involved in the task. In *comply with me*, user let the artifact do the task, there is not an actual balanced collaboration between the user and the artifact nor a direct conversation between them, the artifact complies with its user.

To summarize, there appears to be three relevant characteristics of the *comply with me* relationship. The first is the absence of a balanced collaboration between user and the artifact in order to carry out a task. The user usually acts as someone who gives orders without sufficient knowledge about the ways a task can be achieved, and the artifact is the thing that complies and carries out the task for the user, receiving information from the “situation”. Second, depending on the designer’s intentions and the artifact’s functionality, it could be one or many tasks that the artifact can undertake, complying with the user. Third, the user may not have complete control of this relationship, since this is not a one-to-one conversation, so the user is not the only actor that provides inputs in the form of information.

What about wearable technologies? They are designed to be put on, always connected and in touch with the user’s body, and are free of any specific physical context. What kind of relationships can they create with their user?

“Engage me” Relationship

Wearable technology has led to having small connected computers everywhere all the time. They are usually designed in a way that can be easily worn and be in touch with our bodies. They can collect, analyze and recall data when needed. Personal data are collected by such devices using built-in sensors and Internet connectivity. The information can then be recalled and used to inform users about their actions and activities. The act of being informed about aspects of personal life (e.g. moods, performance, food consumption etc.) through self-tracking technology has been termed the quantified self, lifelogging or personal informatics (e.g. Braber 2016; Li, Day and Forlizzi 2011; Pousman and Stasko 2006). This process of collecting and storing data and then building knowledge from it, in order to provide feedback to users, has been proved to make users reflect on their actions and personal aspects of their lives. Feedback is provided through a user interface (UI) and, in almost all cases, through videos, photos or data visualizations techniques on screens (e.g. Gašević et al. 2014; Kefalidou et al. 2014; Young et al. 2015; Houben et al. 2016).

The relationship here between user, user's data and user's personal goal is what I call an *engage me* relationship. This is the most complex relationship in comparison to the previous ones because it involves the three components of the relationship simultaneously, so the user, the user's personal data and the user's personal goal. For instance, *Fitbit* is a wearable, is a smart bracelet and an activity tracker that tracks user activities, collects data and then provides feedback about, for instance, how many steps have been taken, how many calories have been burned, the user's heart rate and so on. It also supports and motivates users to achieve their predefined goals (Purta et al. 2016).

Thus, the *engage me* relationship has the following fundamental characteristics: 1) the primary relationship is between a user, user's data and her/his personal goal, 2) the artifact is not actually used in order to carry out the task – a bracelet is not used by user in order to run– 3) the artifact is used when carrying out the task, 4) there is no specific place or time for using the artifact.

So, given the analysis of models regarding the way a computing artifact relates to the user and to other components of the system, we can now think about the relationships that the user creates with an IoT system in order to support reflection as a very specific but relational task.

6.2 "Make me think" relationship

The idea of using computing artifacts as tools for enhancing the learning process, creativity and especially for aiding reflective thinking is not new. In particular, designing the features of a computing and interactive artifact in a way that can foster thinking and cognitive development has been the subject of much research in the fields of cognitive and learning science. For instance, Pea's concept of "cognitive technology" is one of the early examples of concepts for designing such artifacts (Pea 1985). This concept involves using computing technology as:

> "mediums" [tools] that help transcend the limitation of mind, such as memory, in activities of thinking, learning and problem solving". (Pea 1985)

Cognitive or mind tools promote learning and thinking *with,* instead of *through,* computers, enabling learning *with* interactive technology as an intellectual and active partner. They are designed and adapted to the learner's environment in order to engage deep reflective thinking and a higher order of critical and meaningful learning. This engagement also helps learners to generate ideas in the context of problem solving (Lajoie and Derry 1993; Jonassen and Reeves 1996).

To summarize, it has been suggested that various interactive technologies seem to be effective in learning and thinking, either *through* and/or *with* them. In this regard, learning *with* interactive technologies or cognitive tool approaches are the focus of more research than ever before. Beaumie and Reeves (2007) built on Salomon's concepts of distributed cognition (1991;1993) and argued:

> ".. the learner, tool, and activity form a joint learning system, and the expertise in the world should be reflected not only in the tool but also in the learning activity within which learners make use of the tool."

Thus, as stated in the above quote, the learner or the user, the computing artifact and the activity or task are components of the learning system, forming a system of relationships as discussed in the earlier sections of this dissertation.

Considering the concepts of cognitive tools, and according to the theory of distributed cognition, the way cognition is distributed is first determined by the intentions of its designer. After that, it is determined by the tool's characteristics, for instance by tool affordances, forms and behaviors (Shackel 1984). Hence, a cognitive or mind tool is essentially an artifact that should be designed in a way that accomplishes their purpose and communicates the designer's intentions (e.g. Crilly 2010). In this regard, reflective thinking is the function of the tool. So, as with any other physical artifacts, it needs to be designed in order to function, thus it requires particular characteristics that enables that function – supporting cognitive activity and reflective thinking in its user.

Interaction with user: user's engagement and tool's transformation

Physically being engaged with and learning with tangible computing artifacts– as active partners– can enhance learning and cognitive development (e.g. Price et. al. 2003; Rogers and Muller 2006). This characteristic or as has been defined earlier, being *Experiential*, has been brought to the design of Sóle, as it is built out of physical modular units. The modularity of the structure helps user to be engaged more with the artifact and experiment with the artifact, which is another important aspect of learning process.

Interaction with the environment and user: communication

Reflection is a process of making sense of one experience, based on the meaning derived and communicated from past experiences (Dewey, 1910; 1933). Building upon a combination of two types of communications, namely across time and space, this level of interaction turns the artifact's transformation and feedbacks to a "text" (Shannon 1948; Crilly 2008). Although the "text" remains open to interpretation in the context of use, it is still clear enough to convey the message. For instance, *Sóle* carries information to the user –regarding to the urban mobility behaviors – by raising the position of the light alongside of the structure.

The *Sóle* communicates this message with the user in an abstract, somehow qualitative way. It is also calm and requires little user's attention (Weiser 2009; Bakker and Eggen 2015). However, the numerical values are always accessible through the mobile application that collects data.

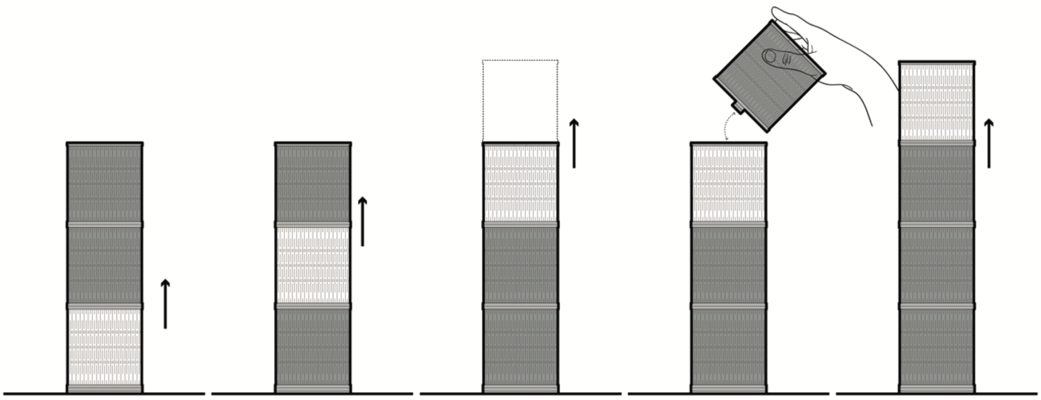

Figure 38: *Sóle*'s transformation and communication.

Interaction with other artifacts and context: deliberation

This level of interaction happens between artifacts and artificial agents. The lamp is connected to other artifacts which can collect data concerning the means of transportation – for instance, the distance traveled in km, fuel consumption, the quantity of CO2 emissions etc. – and send it to the lamp. The mobile application is able to recognize the means of transportation – i.e. it is able to recognize if the user is taking the bus, cycling or walking – amongst other data that it collects.

As the intention for designing *tools for reflection* is to support people in their thinking and reflection, so the relationship that Sóle forms with the user has some similarities to those of *augment me*, *engage me*, but is in contrast with *comply with me*. The *make me think* relationship is an equal, balanced one, similar to the relationship between the user and the artifact in the *augment me* relationship – e.g. a calculator. In these relationships, the user collaborates with the artifact in order to carry out the task – i.e. reflection: thinking about an activity. The *make me think* relationship is similar to the engage me relationship, because the artifact engages and motivates the user, which is required for achieving a goal. The artifact is used also to encourage the user to think about, but not carry out, the task.

So, the characteristics of *make me think relationship* show a mix of some features in *augment me* and *engage me* relationships. Whereas it is in contrast with *comply with me*, because it is designed to change user's behavior, not to comply with them. Furthermore, *make me think* relationship differs from *augment me* since its purpose is not to augment user's abilities to carry out tasks, solving problems faster and in a more efficient way. It differs also from *engage me* relationship, since user might have not only a personal goal for using personal data, but also other goals that will be decided and defined later in time by user – e.g. reducing the negative impacts on environment by frequent bicycle use.

This mixed characteristic of *make me think* relationship is a fundamental driver that might make tools for reflection part of a distinct category of interactive and smart artifacts (Figure 39). This certainly requires the building of a long-term, constant and enduring relationship between the user and the artifact. In order to build such a relationship, tools for reflection need to create thoughtful interactions with the user, instead of merely displaying information.

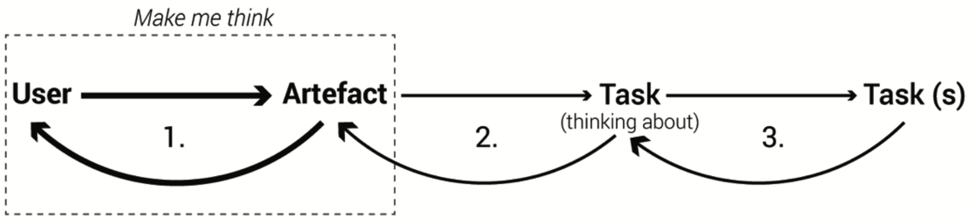

Figure 39: *make me think* relationship.

As an attempt to categorize a new kind of relationship with tools for reflection – which are computing artifacts that support reflection in their user – we can summarize the most important characteristics of the make me think relationship thus: 1) a balanced relationship and collaboration between the user and the artifact; 2) there is a very specific activity that has to be undertaken in relation to the artifact, that is reflective thinking – i.e. which should be related to another activity that needs reflection such as activities related to urban mobility behaviors; 3) the user always has overall control of this relationship; 4) the artifact in this relationship is used to encourage the user to think about, but not carry out, the task – e.g. driving, cycling.

The mobile app senses and collects data related to the user's mobility/transportation activities – walking, cycling and driving – then the lamp lights up in particular ways according to the data received from the mobile app. The behavior of the lamp is the outcome of a system of relationships with other components that are connected to each other.

Chapter Six: Constructing Theories

Chapter 7

Discussions

In this chapter I will discuss and reflect around two current topics that also emerged from this dissertation. The first one is how opting a tool perspective in designing and analyzing tools for reflection can be useful. I will include into this discussion the role of the forms and form giving practices in the HCI. I will reflect on how I gave form to a *Tool for Reflection* as a computed, smart and connected object, and how this form giving practice has been related to tool perspective. The second one is around a new topic that sees designing as a way of making theories, but also how designing can be informed by theories.

7.1 Giving form to *Tools for Reflection*

Users can physically be engaged with a *Tool for Reflection*, this enables experimentation and open ended reflection, while keeping the identity of the tool as an everyday, functional object. In chapter three, for instance, being *experiential* is described as one of the characteristic of the *Tool for Reflection,* that shows the ability of building and shaping a tool, *in order to think with* as a task that it supports. The physical form needs to support the functionality of the tool's characteristic, so in giving form to *Sóle* it has been considered. For instance, it has been designed in modular unites, that enable user to build it and also to add more units. This emphasizes the important role of the designer of the tool, her/his ability to give form to such object that makes it understandable as such. Form giving is the ability of designer to identify form attributes that convey information about non-perceptible characters of artefacts as informed by Gibson's ecological perception (Smet, Overbeeke and Gaver 1994). The form of an object, or the product semantics, can communicate the object's function, characters and its context of use (Janlert and Stolterman 1997; Krippendorff 1989). And as Krippendorff affirms form and meaning are, indeed, intrinsically correlated and they must make sense to be understood and used (Krippendorff 2006).

The fixed *Structure* in Gero's *FBS (Function, Behavior, Structure)* framework, is actually the physical form of the artifact, which enables its behaviors in order to achieve its goal and function (Gero, 1996). In addition, physical forms are the structures for information that should be conveyed to the user. *Tools for reflection* as computing and smart objects, in addition to the physical forms, have also temporal forms. While physical forms are three-dimensional tangible shapes, temporal forms are the pattern of the transitions between states that a computing artifact produces during time (Vallgårda and Redström 2014). While the physical form is related to the space and setting, the temporal form is related to the time. The character of an artifact is another attribute that is expresses through its forms and behaviors. For instance, Janlert and Stolterman emphasize on the overall character of the artifact that are defined thanks to their form and appearance (1997). For instance, *Sóle* has a calm presence, its physical and behavioral presence are unobtrusive, because it is a lamp and it provides light. Its forms –physical and temporal– are unobtrusive, they support user and do not dominate. [7]

In addition, in this dissertation I sought to describe the process of form giving to *Sóle* as a *Tool for Reflection* in chapter 5. I have described that the form giving to *Sóle* included in the concept-driven approach involved two practical activities of Sketching and Prototyping during the "Concept Appropriating" phase. But I would argue that the form giving process, as the activity of giving form –physical or temporal– to non-perceptible attributes of a product, for me has been started since the "Concept Defining" phase. Indeed, some physical forms, their functions and how they can be related to characters of a *Tool for Reflection* have been already highlighted in a table 1 in chapter 3, whereas I sought to validate the concept through Gero's FBS framework. So, the form giving process, partially has been carried analytically prior to a more practical work. It first occurred in my mind, considering alternatives, imagining the forms, going back and forth between concepts, definitions, characters and my imaginations, which I wrote them down using words. Then I used my hands to sketch real forms that partially have been defined in "Concept Defining", I refined them and made them tangible (Figure 40).

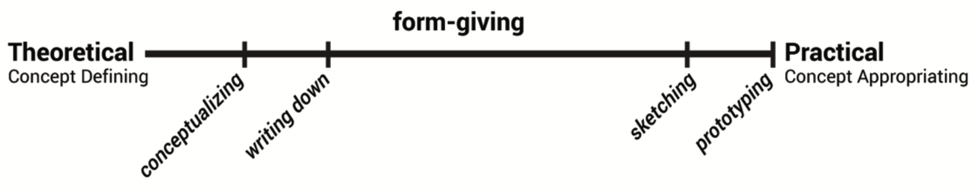

Figure 40: Giving form to *Sóle* in Concept-Driven approach.

[7] Dieter Rams's good design. (www.vitsoe.com/us/about/good-design)

7.2 'Reflection' as a Reference Task

Reflection as a way of thinking is not just an individual and internal process, but requires external stimuli: objects, other people, activities and the environment are all important in the process (Salomon 1993; Rogers 1997). Reflection needs continuity while helping people to acquire a deeper understanding of a situation and then take careful and informed courses of action for change (Sengers et al. 2005; Schön 1983; Dewey 1933). Reflective reasoning is a deep, slow and effortful process (Norman 1993, pp 25). It requires moments of quiet, but also the aid of external support, such as writing, using computing tools, reading books etc. Unlike experiential thinking, reflective thinking is not autonomous or reactive, but rather is about concepts, reconsideration, planning and decision-making. It is not about the elaboration of the information structure that already exists in our brain (Norman 1993).

Reflection can be considered as a user activity or a reference task (Whittaker, Terveen and Nardi 2000) that a *Tool for Reflection* can support. However, a *Tool for Reflection* differs from other artifacts that support a user's activities, in some fundamental aspects: 1) the user does not necessarily undertake their daily activity using a *Tool for Reflection* – e.g. they do not drive or cycle using a lamp – rather the presence of the artifact supports reflection about other activities than that the object is used for. So, the object recalls the experiences and memories associated with it, so reflection can be considered as a process of *thinking about* an activity; 2) the user thinks about an activity *with* the *Tool for Reflection* rather than *through* it – i.e. it does not function as an object in the hand of its user, but rather as a partner. Accordingly, the reference task becomes a *relational task* that relates to the object (maybe over long periods) rather than serving merely as a tool for solving a particular task.

Reflection is not, as such, a user's problem to be solved, but rather an ongoing activity that should be continuously supported. This is definitely a challenge for interaction designers – how to design tools for supporting a continuous activity (i.e. reflection), rather than designing for activities that are essentially easily and efficiently solved problems, which is the typical model behind the design of computational tools.

7.3 Designing (with) theories

In reflecting upon the process of this dissertation, as it has been unfolded during this project, there are a number of implications for the development of design theory, and implications for carrying out this type of research through design. This dissertation is another attempt to contribute to the HCI and design community, by providing an example of designing with theories.

Theory for me worked as a design material. It has been blended into the whole process, by shaping, supporting and validating the design process. It has been also constraining, similar to any other design material and tool, that can support but have also their limitations. I consulted and used theories since the very early stage of my design research. Similar to the nature of any other design process, I iterate: I went through the design process with theories, then I have also designed theories, which they can be used again for designing in future projects. I went through the process of designing with theories using them as shaping, contextualizing and analytical tools throughout my dissertation and in different stages (Beck and Stolterman 2016; Bardzell 2016). The way I used theory in some parts of my dissertation, does not actually fit into one category, instead it is a combination of some of them. And I believe this is due to the nature of design process, its materials, resources, people and in general the context of the design work. As Donald Schön states, designer is in a reflective conversation with the materials at hand and so the outcome of the design is influenced by materials and resources available during design process.

I used theory as a shaping tool for "“Concept Defining”", when I ideated and developed the concept of my dissertation after a literature analysis on the links between behaviors, reflective thinking and physical and smart artifacts. Further I defined the concept: *Tool for Reflection*. It has been defined through an analysis of the characteristics of physical objects and smart objects, in order to find out the additional characteristics of *Tool for Reflection*. To this aim, I consulted the literature about the functions and properties, of artifacts in general and the smart objects. Then I used theory as analytical tool, for validating this concept. In this stage I used Gero's FBS (Function, Behavior, Structure) framework, in order to validate the functions, according to the external, internal, fixed and situated structures of the *Tool for Reflection*.

Then I used theories as contextualising tool for "“Concept Situating”". I used existing theories in architecture about spaces and their configurations, home computing and also Alexander's patterns of activities in order to understand the relation between spaces, activities and objects in home environment. Then I conducted a participatory session to study further these relations. My project has been influenced also by the theories on Place in humanistic geography, which is about how a locale, a spatial configuration become a human product, thanks to the influences of its inhabitants, their activities, routines, emotions and etc. related to that space.

I did not probably use theories in "“Concept Appropriating”" stage, as this stage was mostly about designing the artifact, defining its technical specifications, drawings and prototyping.

Design materials, design process and the designer are continuously being influenced by each other and re-shaped during the design process. The theory as a design material is not an exception in this regard.

In "constructing theories" stage of my dissertation, instead the theory was the artifact, the product itself. I sought to construct theoretical models of relationships with existing computing artifacts, rhetorically by observing and analysing some examples of computing artifacts. Then I went through an analysis of the characteristics of the *Sóle* prototype in relation to the user, the environment and other objects. This analysis led to a theoretical model that show the type of relationship with a *Tool for Reflection*.

Designing for reflection as a design theory

A typical design project, starts with a design problem or a design brief. However, reflection is not a problem to be solved, or a need expressed by users. In addition, we already think with objects as Turkle stated (Turkle 2011). So, instead of tackling the project from one such perspective, I needed to see the project as a process that would encompass reflection as an on-going activity being empowered with computational tools. At the same time, we know that any tool changes the activity it supports, no matter whether the tool is a hammer or a "smart object". Accordingly, we not only had to maintain a focus on reflection as an activity undertaken with this object, but also had to keep revising our ideas about what reflection is as a concept on a more theoretical level, as this project moved forward.

On a practical level, a more general lesson to be learnt from this project is that not only the design activity that redefines or resolves problems, but also the design purpose that challenge and change the ideas guiding the design. In this project, supporting reflective thinking was the purpose of design instead of being a problem to be solved. So, the whole process has been tailored according to that purpose. Therefore, design concepts have not been seen as a starting point for design project, nor as a stable construct throughout a project, but rather as a theoretical factor that also changes as the project moves from early drafts to the final design. Design theory (and to theorize design) is not separable from the design process, just as our everyday objects that we think with cannot be separated from the activity of reflection.

If our theoretical notions change over the course of a design project, then that also has implications for the research design. This project, with a focus on designing for reflection, has identified this fact, and has illustrated how the design research not only needs to be iterative in terms of alternating between theories on reflection and practical design work in designing for reflection, but how each step of the research process needs to bridge between the design concepts that guide the design process, and the designed artifacts that illustrate the ideas in material and computational form.

Chapter Seven: Discussions

Chapter 8

Conclusions

The idea of using computing artifacts as tools for enhancing learning process, creativity and especially for aiding critical thinking is not new. In particular, designing the features of a computing and interactive artifact in a way that can foster thinking and cognitive development has been the subject of many researches in cognitive and learning science areas.

It has been also long debated that various interactive technologies seem to be effective in learning and thinking, either *through* and/or *with* them. In this regard, the learning *with* interactive technologies or cognitive and mind tool approaches are the focus of more researches than ever before.

In this dissertation, I sought to inform my work from theories in cognitive technologies, distributed cognition and reflective thinking in order to define a design concept. I defined the term *tools for reflection* as the category of computing and smart artifacts, able to log and collect data and provide tangible feedbacks for evoking thoughts and reflection in user with the purpose of conscious and mindful behavior change in user. In particular, I sought to emphasize on two main aspects: 1) the role of materiality and physicality of the artifacts to evoke reflective thinking in user and defined the physical and interactional characteristics of the *Tool for Reflection,* 2) the of the particular relationship that a *Tool for Reflection* create with its user, its environment and also other objects.

In designing interactive artifacts for reflection, I suggest to pay more attention to the materiality and physicality of the interactive artifact, its characters and its relationships, so the feedbacks provided by the artifact become naturally more qualitative rather than quantitative –i.e. numerical values on displays. I believe this is relevant because reflection as an activity requires external stimuli such as physical objects, writing activities and talking and sharing with other people.

In this dissertation, I went through an iterative process of designing with theories; and design of theories. I used and designed with theories and made theoretical models from a designed artifact. I followed a concept-driven approach for this dissertation, whereas the design concept has been inspired by theories and/or empirical studies and then the concept itself can contribute to the theory. I started this project with a literature analysis in order to find a concept: tools for reflection. Then I defined and validated the concept. Furthermore, I went through analytical and empirical works in order to situated the concept, defining a suitable physical context and a particular behavior for it. Then I went through designing and prototyping, from which thereafter I sought to draw theoretical models.

This dissertation, can contribute to the both communities of HCI and design. My research contains the theoretical, methodological and practical contributions. My research methodology on that how theory and designing have informed each other throughout the design process contribute to the community of design practice mostly. The way my research approached the area of designing for reflection, as a very specific area, contributes mainly to the HCI field. The guidelines and in particular, the characteristics of the artifacts that can stimulate reflection, which I provided through my research is a practical contribution to the HCI community. Informing from design field, these guidelines can be repeated or building upon for future works in the area of reflection. In addition, the way I made these guidelines and artifact's properties can be replicated and used for design of other artifacts with other purposes within HCI.

8.1 Future works

Yet Human-Computer Interaction?

In After Interaction, Alex Taylor highlights, that interaction as a concept contributes to separation rather than connections and relationships (Taylor 2015). Since the concept of interaction deliberately makes a clear division between people, computing artifacts and environments, it cannot be suitable for studying the systems of computing artifacts such as the Internet of Things. There is a need to developing a new approach that views computing artifacts in relation to their user, to their physical and cultural context and not as stand-alone products, focusing on the purpose of that relationship.

During my research, I sought to develop a relational approach and a modeling technique for such a purpose. This modeling technique and approach can not only help to understand the relationships between components of an existing IoT system –a user, a smart object and a situation– but also can be used for designing new IoT systems.

Designing places for reflection

Sherry Turkle in her book, *The Evocative Objects*, points out that we often consider objects as useful or aesthetic, but rarely count them as our companions or as provocations to thoughts. Indeed, our thinking is considerably related to the objects with which we interact, and also to the space we live within: the architectural three-dimensional space, where we spend our times within, doing various activities, using numerous objects.

So how can spaces serve as scaffolds for thinking? And how can we design such spaces as part of a larger system of connected things in the so-called Internet of Things? For sure, the Internet of Things comes with the promise of a nearby future filled with networked smart objects. But how can we align one such technology-driven agenda with a vision of how smart objects not only bring computation to the environments they are part to, but also how such computational objects might be designed both in relation to the places that constitute our everyday environment, and to our everyday thinking?

I believe this is also an opportunity for future researches. In my research, I started to contribute to this stream of research by considering “reflective thinking” as it is situated in space in relation to smart objects. I considered reflective thinking as an opportunity to dwell with technology in our spaces. Further on, knowing that “thinking” is an object-dependent activity situated in a place, interrelated with many external factors, I grounded my work in the theory of distributed cognition.

As a contribution, I provided models intended to clarify the relations between “thinking” and the external factors that influence them. Then some guidelines for designing “Places” for thinking have been suggested. With this as a concept, three types of interaction have been presented. I presented this research as a preliminary design guidelines or as a conceptual framework, with a potential to become an emergent design space in the HCI.

References

Agnew J.A. (1987) Place and politics: the geographical mediation of state and society. *Progress in Human Geography* 27(5), 605-614.

Allen P. V. (2007). *The New Ecology of Things*. Media Design Program at Art Center College of Design; Limited edition.

Allmendinger G. and Lombreglia R. (2005). *Four Strategies for the Age of Smart Services,* Harvard Business Review, 83(10): 131– 145.

Anderson, E., F., McLoughlin, L. (2007). *Critters in the classroom: a 3D computer-game-like tool for teaching programming to computer animation students.* In: Proceedings of the ACM SIGGRAPH 2007 educators program Conference, pp. 7.

Ashton, K., (2009). That 'Internet of Things' Thing, in the real-world things matter more than ideas. *RFID J.*, 1-2.

Atzori L., Iera A., Morabito G., (2014). From "Smart Artifacts" to "Social Artifacts": The next evolutionary step to the Internet of Things, *IEEE Communication Magazine* 52, 97-105.

Baber, C., Stanton, N.A., (1996). Human error identification techniques applied to public technology: predictions compared with observed use. *Applied Ergonomics* 27 (2), 119–131.

Bakker S., Hoven E., Eggen (2015). *Peripheral interaction: characteristics and considerations. Personal and Ubiquitous Computing* 19(1): 239-254.

Banathy, B. A. (1996), Information-based design of social systems. Systems Research 41: 104–123. doi:10.1002/bs.3830410202.

Bardzell J. (2016) Commentary on "Examining Practical, Everyday Theory Use in Design Research". *SheJi: The journal of design, economics and innovation*. 2(2) 143-145.

Bardzell J. Bardzell S. (2015) *Immodest proposals: Research through design and knowledge*. In proceedings of CHI'15, pp 2093-2102. ACM.

Baumer, E. P. S., Khovanskaya, V., Matthews, M., Reynolds, L., Schwanda Sosik, V., & Gay, G. (2014). *Reviewing Reflection: On the Use of Reflection in Interactive System Design.* In Proceedings of the 2014 Conference on Designing Interactive Systems (pp. 93–102). New York, NY, USA: ACM.

Beaumie, K., Reeves, T. C. (2007). Reframing research on learning with technology: in search of the meaning of cognitive tools, *Instructional Science*, 35(3) 207-256.

Beck J., Stolterman E. (2016) Examining practical, everyday theory use in design research. *SheJi: The journal of design, economics and innovation.* 2(2) 125-140.

Bekker, M.M. and Vermeeren A., (1993). Developing user interface design tools: an analysis of interface design practice. *Contemporary Ergonomics*, 79-84.

Bellinger G., Castro D., Mills A., (2004). *Data, Information, Knowledge and Wisdom, Systems Thinking*, pp 5.

Bertalanffy, L. (1968). *General system theory: Foundations, development, applications.* New York: G. Braziller.

Binder T., De Michelis G., Ehn, P., Jacucci, G., Linde, P., Wagner, I. (2011). *Design Things*. Cambridge: MIT press.

Bleeker, J. (2006) A Manifesto for Networked Objects — Cohabiting with Pigeons, Arphids and Aibos in the Internet of Things. http://nearfuturelaboratory.com/files/WhyThingsMatter.pdf. Last access July 2016.

Braber M. D. (2016), The emergence of Quantified Self as a Data-driven Movement to Promote Health and Wellness. In proceedings of the first workshop on lifelogging tools and applications (LTA'16). Amsterdam, The Netherlands, ACM: New York.

Bucciarelli, L. L. (1984). Reflective practice in engineering design. *Design Studies,* 5(3), 185–190.

Bunton, D. (2002). Generic moves in PhD thesis introductions. In *Academic discourse*, di J. Flowerdew, 57-75. London: Pearson Education Limited.

Carroll M. J., Kellogg W. A. (1989). *Artifact as theory-nexus: hermeneutics meets theory-based design.* In Proceeding of CHI'89, pp 7-14. ACM.

Churchman, C. W. (1968). *The Systems Approach*. New York: Delacorte Press.

Cialdini, R. B. (2007). *Influence: The Psychology of Persuasion*. New York: HarperBusines.

Clancey, William J. (1997). *Situated Cognition*. Cambridge University Press, Cambridge, 1997.

Clune, S. (2010). Design for Behavioural Change, *Journal of Design Strategies* 4, 68-75.

Cresswell, T. (2009). *Place.* In N. Thrift, & R. Kitchen (Eds.), *International Encyclopedia of Human Geography.* (Vol. 8, pp. 169-177). Oxford: Elsevier.

Cresswell, T. (2011). *Place: Part II*. In J. Agnew, & J. Duncan (Eds.), *The Wiley-Blackwell Companion to Human Geography.* Oxford: Blackwell.

Creswell, T. (2015). *Place: An introduction.* Wiley-Blackwell.

Crilly, N. (2010). The roles that artifacts play: technical, social and aesthetic functions. *Design Studies*, 31(4) 311-344.

Crilly, N., Good, D., Matravers, D., Clarkson, P. J. (2008). Design as communication: exploring the validity and utility of relating intention to interpretation. *Design Studies* 29(5), 425 – 457.

Cross, N. (1982). Designerly ways of knowing. *Design Studies.* 3(4), 221-227.

Cross, N., Christiaans H., Dorst K. (1996). *Analyzing design activity*. Wiley & Sons.

Cross, N. (2000). *Engineering design methods: strategies for product design.* Wiley & Sons.

Cross, N. (2001). Designerly ways of knowing: Design discipline versus design science. *Design Studies.* 17(3), 49-55.

Cross, N. (2006) Designerly Ways of Knowing. In: Designerly Ways of Knowing. Springer, London

Cross, N. (2011). *Design Thinking: Understanding How Designers Think and Work.* Oxford: Berg Publishers.

Dalsgaard, P. (2014) Pragmatism and design thinking. *International journal of design* 8(1), 143-155.

Denzin, N. K. (2012) Triangulation 2.0. *Journal of mixed methods research*, 6(2) 80-88.

Dewey, J. (1933). *How We Think. A restatement of the relation of reflective thinking to the educative process*. Boston: D. C. Heath and Company.

Dietrich, M., Van Laerhoven K. (2014). *Recall your Actions! Using Wearable Activity Recognition to Augment the Human Mind.* In Proceeding of Ubicomp '14 Adjunct. Seattle, WA, USA.

Dietrich, M., Van Laerhoven K. (2016). An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity. *Philosophies*, vol:1, 55-67.

Dix, A. (2009). Human-computer Interaction. In L. Liu, M. T. Özsu (Eds.) *Encyclopedia of database systems*, pp 1327-1331: Springer, US.

Dorst, K. (2004). On the problem of design problems – problem solving and design exprtise. *Journal of Design Research*, 4(2).

Dorst, K. (2007). On the conceptual framework of John Gero's FBS-model and the prescriptive aims of design methodology. *Design Studies,* 28(2), 133-157.

Dorst, K. (2011). The core of 'design thinking' and its applications. *Design Studies* 32(6), 521-532.

Dourish, P. (2004). *Where the Action is*. Cambridge: MIT Press.

Dourish, P., Mazmanian, M. (2011). *Media as material: information representations as material foundations for organizational practice*. In Proceedings of the 3rd international symposium on process organization studies. Corfu, Greece.

Dourish, P. (2004). What we talk about, when we talk about context. *Personal and Ubiquitous Computing* 8 (1), 19-30.

Ericsson Consumer Insight Summary Report June 2015. https://www.ericsson.com/res/docs/2015/consumerlab/ericsson-consumerlab-connected-homes.pdf, Last access July 2 2016.

Eriksson K., Lindström UA. (1997). Abduction, a way of deeper understanding of the world of caring. *Scandinavian journal of caring sciences,* 11(4) 195-198.

Fjord, The Era of Living Services Report September 2015, https://livingservices.fjordnet.com/media-files/2015/09/living-services.pdf, Last access July 2 2016.

Fleck, R. (2012). *Designing for Reflection, Sustainability and Simplicity*, Presented at: Workshop on Simple, Sustainable living, CHI'12, Austin, Texas.

Fleck, R., Fitzpatrick G. (2010). *Reflecting on Reflection: Framing Design Landscape.* In Proceedings of the 22nd Conference of the Computer-Human Interaction, Special Interest Group of Australia on Computer-Human Interaction, 216-223.

Fogg, B. J. (2009). The new rules of persuasion. *RSA Journal.* 155 (5538), 24-29.

Fogg, B. J. (1998). *Persuasive computers: Perspectives and research directions*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems 225–232.

Fogg, B. J. (2003). *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco: Morgan Kaufman.

Foltyn, L., Tozicka, J., Rollo, M., Pechoucek, M., Jisl, P. (2006) *Reflective-Cognitive Architecture: From Abstract Concept to Self-Adapting Agent.* In Proceedings of DIS Conference: IEEE Workshop on Distributed Intelligent Systems - Collective Intelligence and Its Applications.

Fortino, G., Guerrini A., Russo W. (2012). *Agent-oriented Smart Artifacts development.* In proceeding of the 16th International conference on Computer Supported Cooperative Work in Design, 907-912.

Froehlich, J., Findlater L., Ostergren, M., Ramanathan, S., Peterson J., Wragg I., Larson, E. (2012). *The Design and Evaluation of Prototype Eco-feedback Displays for Fixture-level Water Usage Data.* In: Proceedings of the ACM CHI'12 Conference on Human Factors in Computing Systems, 2367–2376.

Gašević, D., Mirriahi N., Dawson S. (2014). Analytics of the effects of video use and instruction to support reflective learning. In proceedings of the 4th International Conference on Learning and Analytics and Knowledge (LAK'14), 123-132. Indianapolis, IN, USA. ACM: New York.

Gaver, W. W. (1997). Auditory interfaces. In M. G. Helander, T. K. Landauer and P. V. Prabhu (Eds.) *Handbook of Human-Computer Interaction* (pp. 1003-1041). Elsevier.

Gaver, W. W., Beaver, J., Benford, S. (2003). *Ambiguity as a resource for design*. In Proceedings of ACM CHI'3 Conference on Human Factors in Computing Systems. 233-240.

Gero, J. (1998). Conceptual designing as a sequence of situated acts. *Artificial intelligence in structural engineering.* 165-177.

Gero, J. (1990). Design Prototypes: A Knowledge Representation Schema for Design, *AI Magazine*, 11(4), 26.

Gero, J., Kannengiesser, U. (2003). *Function-Behavior-Structure: A model for social situated agents*. Workshop on Cognitive Modeling of Agents and Multi-Agent Interactions, International Joint Conference on Artificial Intelligence 101, 107.

Gibson, J. J. (1977). The Theory of Affordances. In Shaw, R., and Bransford, J., (Eds.) *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*. Lawrence Erlbaum.

Goguen, (Eds.). *Requirements engineering: Social and technical issues*, London, Academic Press, 217-240.

Goldkuhl, G. (2011). *Design research is search for a paradigm: pragmatism is the answer*. In M Helfert and B. Donnellan (Eds): Communications in computer and information science, 286, pp.84-95.

Greeno, J. G., & Moore, J. L. (1993). Situativity and symbols: Response to Vera and Simon. *Cognitive Science* 17, 49-60.

Gustafson, K., Bennett, W. (1999). *Issues and Difficulties in Promoting Learner Reflection: Results from a Three-Year Study*. http://it.coe.uga.edu/kgustafs/document/promoting.htm

Hallnäs, L., Redström, J. (2001). Slow Technology, Designing for Reflection. *Personal and Ubiquitous Computing,* 5(3), 201-212.

Hardin, G. (1993) *Living Within Limits: Ecology, Economics, and Population Taboos.* Oxford university press: New York.

Harman, G. (2002) *Tool-being: Heidegger and the metaphysics of objects*. Carus Publishing Company.

Harrison, S., Dourish P. (1996) *Re-place-ing space: the roles of place and space in collaborative systems*. In proceeding of CSCW'96 conference, pp 67-76.

Heidegger, M., (1962) *Being and Time*, trans. John Macquarrie and Edward Robinson. New York: Harper & Row.

Hornecker, E., Buur, J. (2006). *Getting a grip on tangible interaction: a framework on physical space and social interaction*. In Proceedings of the SIGCHI conference on Human Factors in computing systems, pp. 437-446.

Houben, S., Golsteijn C., Gallacher S., Johnson R., Bakker S., Marquardt N., Capra L., Rogers Y. (2016). *Physikit: Data Engagement Through Physical Ambient*

Visualizations in the Home. In Proceeding of the CHI' 16, the SIGCHI conference on Human Factors in computing systems. 1608-1619.

Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT press.

Hyodo, J. (2011). Can Colors Make Me Happy? The Effect of Color on Mood: A Meta-Analysis. *Advances in Consumer Research* 2, 858-868.

Ishii, H., Lakatos, D., Bonanni, L., Labrune, J. B. (2012). Radical Atoms: Beyond Tangible Bits*, Interactions,* 1, 38-51.

Ishii, H., Ullmer, B. (1997). *Tangible bits: towards seamless interfaces between people, bits and atoms.* In Proceedings of the SIGCHI conference on Human factors in computing systems, 241.

Janlert, L-E, Stolterman E. (1997). The character of things. *Design Studies* 18, 297-314.

Janlert, L-E., Stolterman E. (2014). Faceless Interaction–A conceptual Examination of the Notion of Interface: Past, Present, and Future. *Human-Computer Interaction*, 30(6), 507-539.

Janlert, L-E., & Stolterman, E. (2016). The meaning of interactivity—some proposals for definitions and measures. *Human–Computer Interaction*, 32(3), 103-138.

Jenkins, T. (2015). *Designing the "Things" of IoT.* In Proceedings of the 9th International Conference on Tangible, Embedded and Embodied Interaction (TEI' 15), 449-452.

Jonassen, D. H. (1997). Instructional Design Models for Well-Structured and Ill-Structured Problem-Solving Learning Outcomes. *Educational Technology Research and Development*. 45 (1): 65–94.

Jonassen, D. H., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonassen (Ed.), Handbook of research for educational communications and technology, 1st edition. (pp. 693-719). New York: Macmillan.

John Christopher, J. (1970). *Design Methods: seeds of human futures*, John Wiley & Sons Ltd., London. 2nd edition, John Wiley & Sons Ltd., 1992.

John Christopher, J. (1991). *Designing Designing*. Architecture Design and Technology Press.

Kalnikaité V., Whittaker S. (2011). A saunter down memory lane: Digital reflection on personal mementos. *International journal of human-computer studies*, 69(5), 298-310.

Kaptelinin V., Nardi B. A. (2006). Acting with technology, activity theory and interaction design. MIT Press: Cambridge, MA.

Kay, A. C. (1972). *A Personal Computer for Children of All Ages*. In Proceeding of ACM'72 Annual Conference.

Kefalidou G., Skatova A., Brown M., Shipp V., Pinchin J., Kelly P., Dix A., Sun X., (2014) *Enhancing self-reflection with wearable sensors.* In proceedings of MobileHCI'14, pp. 577-580. ACM.

Kolko, J. (2011). *Thoughts on interaction design*. Elsevier (second Ed.).

Kortuem, G., Kowsar, F., Fitton, D., Vasughi, S. (2010). Smart artifacts as building blocks for the Internet of things*, Journal of Internet Computing, IEEE,* 14(1), 44 – 51.

Kramer, G. (1993). *Auditory Display: Sonification, Audification, and Auditory Interfaces.* Perseus Publishing.

Kuniavsky, M. (2010). *Design of Smart Things*. Morgan Kaufmann.

Kwan, Becky S.C. 2009. «Reading in preparation for writing a PhD thesis: Case studies of exp Ackoff, R. L., From Data to Wisdom (1989). *Journal of Applies Systems Analysis*. 16, 3-9.

Lajoie, S. P., & Derry, S. J. (Eds.). (1993). *Computers as cognitive tools*. Hillsdale, NJ: Lawrence Erlbaum.

Li, I., Dey, A., Forlizzi, J. (2011). *Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies*. In Proceedings of the 13th international conference on Ubiquitous computing, pp 405-414.

Lim Y., Stolterman E., Tenenberg J. (2008). The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 15 (2), 7-27.

Lin, J., Mamykina, L,, Lindtner, S,, Delajoux, G., Strub, H. (2006). *Fish'n'Steps: encouraging physical activity with an interactive computer game*. In Proceedings of UbiComp 2006. Springer, Berlin, pp 261-278.

Lockton, D., Harrison, D., Stanton, N. A. (2010). The Design with Intent Method: a design tool for influencing user behaviour. *Applied Ergonomics*. 41 (3), 382-392.

Löwgren, J., Stolterman, E. (2004). *Thoughtful Interaction Design*. Cambridge: MIT Press.

Malafouris, L. (2008). At the Potter's Wheel: An Argument for Material Agency. In *The Material Agency* Lambros Malafouris and Lambros Knappett (eds.). Springer US, 19-36.

Mazalek, A., Hoven, E. V. D. (2009). Framing Tangible Interaction Frameworks. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 3, 225-235.

Moggridge, B. (2007), *Designing Interactions*, Cambridge: MIT Press.

Moon, J. (1999). *Reflection in Learning & Professional Development*. Abingdon, Oxon: Routledge Falmer.

Morgan D. (2014). Pragmatism as a paradigm for social research. *Qualitative Inquiry* 20(8) 1045-1053.

Mühlhäuser, M., (2008). *Smart Products: An Introduction*, *Communications in Computer and Information Science*, Springer, 11, 158-164.

Nelson, H. G., Stolterman E. (2014), *The design way*. Cambridge: MIT press.

Niedderer, K. (2007). Designing Mindful Interaction: The Category of Performative Artifact. *Design Issues*, 23(1), 3-17.

Niedderer, K. (2013). *Mindful Design as a Driver for Social Behaviour Change*. In Proceedings of the IASDR Conference, Tokyo, Japan: IASDR.

Norman, D. (2013). *The Design of Everyday Things*, 1988. New York: Basic Books.

Norman, D. (2007). *The Design of Future Things*, New York: Basic Books.

Norman, D. (1993). *Things that make us smart: defending human attributes in the age of the machine*, Boston, MA: Addison-Wesley Longman Publishing Co., Inc.

Oduor, M., Alahaivala, T., Oinas-Kukkonen, H. (2014). Persuasive software design patterns for social influence. *Personal and Ubiquitous Computing* 18(7), 1689-1704.

Ortin, F., Cueva, J. M. (2003). Non-restrictive computational reflection. *Journal of Computer Standards & Interfaces*. 25, 241-251.

Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.

Parker A. G. (2014). Reflection-through-performance: personal implications of documenting health behaviors for the collective. Personal and Ubiquitous Computing, 18 (7), 1737-1752.

Pea, R. (1985). Beyond amplification: using the computer to reorganize mental functioning. *Educational Psychologist*, 20, 176–182.

Pea, R.D. (1993). *Practices of distributed intelligence and designs for education*. In G. Salomon (Ed.), Distributed cognitions: Psychological and educational considerations (pp. 47-87). New York: Cambridge University Press.

Perkins, D.N. (1993). *Person-plus: A distributed view of thinking and learning*. In G. Salomon (Ed.), Distributed cognitions. Psychological and educational considerations (pp. 88-110). NY: Cambridge University Press.

Piaget, J. (1947). *The Psychology of Intelligence*. New York: Routledge.

Pierce C. S. (1868). Some consequences for four incapacities. *The journal of speculative philosophy,* 2(3) 140-157.

Ploderer B., Reitberger W., Oinas-Kukkonen H., Gemert-Pijnen J., (2014). Social Interaction and reflection for behavior change*, Personal and Ubiquitous Computing* 18(7), 1667-1676.

Pousman Z., Stasko J. (2006). *A taxonomy of ambient information systems: four patterns of design.* In Proceedings of the working conference on Advanced visual interfaces, pp. 67-74.

Prabu, W., Haruo, H., and Shinichi K. (2012). Effects of Interior Colors, Lighting and Decors on Perceived Sociability, Emotion and Behavior Related to Social Dining. *Procedia - Social and Behavioral Sciences* 38, 362–372.

Preece, J., Rogers, Y. and Sharp, H., (2002). *Interaction design: beyond human-computer interaction.* New York: John Wiley & Sons.

Price, S., Rogers, Y., Scaife, M., Stanton, D., Neale, H., (2003). Using 'tangibles' to promote novel forms of playful learning. *Interacting with computers* 15, 169-185.

Purta R., Mattingly S., Song L., Lizardo O., Hachen D., Poellabauer, Striegel A. (2016). *Experiences measuring sleep and physical activity pattern across a large college cohort with fitbits.* In proceedings of the International Symposium on Wearable Computers (ISWC'16), 28-35. Heidelberg, Germany. ACM: New York.

Quantified-Self: Self-knowledge through numbers. Available online: http://www.quantifiedself.com Last access on 23 November 2015.

Reeves, L. M., Martin J. C., McTear, M., Raman, K. M., Stanney, Qian Ying Wang H., Lai, J., Larson, J., Oviatt, S., Balaji, T. S., Buisine, S., Collings, P., Cohen, P., Kraal, B. (2004). Guidelines for multimodal user interface design, *ACM Communication*, 47 (1) 57-59.

Reitberger, W., Ploderer, B., Obermair C, Tscheligi M. (2007). *The perCues framework and its application for sustainable mobility*. In Proceedings of PERSUASIVE, 92–95.

Rinott M., Geiger S., Gal-Or E., Or L. (2013). *Cubes.* In Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, pp. 397-398. ACM.

Rittel, H. W. J., Webber, M. M. (1973), Dilemmas in a general theory of planning. *Policy Science* 4(2), 155-169.

Robbins H., Giaccardi E., Karana E. (2016). *Traces as an Approach to Design for Focal Things and Practices.* In Proceedings of the 9th NordiCHI, article No. 19.

Rodgers C., (2002), Defining Reflection: Another Look at John Dewey and Reflective Thinking, *Teachers College Record* 104:4, 842-866.

Rogers Y. 1997. A Brief Introduction to Distributed Cognition. Retrieved March 12, 2017 from: http://mcs.open.ac.uk/yr258/papers/dcog/dcog-brief-intro.pdf.

Rogers, Y., Muller, H. (2006). A framework for designing sensor-based interactions to promote exploration and reflection in play. *International Journal of Human-Computer Studies*. 64, 1-14.

Rose, D. (2014), *Enchanted Artifacts: Design, Human desire and the Internet of Things*. Scribner.

Sabou, M., (2010). Smart Artifacts: Challenges for Semantic Web Research, *Semantic Web - Interoperability, Usability, Applicability* 1, 1–5.

Salomon, G. (1993). *Distributed cognitions: Psychological and educational considerations*. New York: Cambridge University Press.

Sas, C., Dix, A. (2011). Designing for reflection on personal experience. *International Journal of Human-Computer Studies*. 69, 281-282.

Schifferstein H. N. J., Özcan E., Rozendaal M. C. (2015) *Towards the maturation of design: From smart to wise products*. In Proceeding of DesForm Conference, Milan, Italy.

Schifferstein, H. N. J., Hekkert, P. (2008). *Product experience*. Amsterdam, the Netherlands: Elsevier.

Schön, D. (1991). Designing as reflective conversation with the materials of a design situation. *Research in engineering design* 3(3), 131–147.

Schön, D. (1988). Designing: Rules, types and worlds. *Design Studies* 9, 24-38.

Schön D. (1983). *The reflective practitioner: how professionals think in action*. New York: Basic Books.

Schultz P.W., Shriver C., Tabanico J. J., Khazian A. M. (2004) Implicit connections with nature. *Journal of environmental psychology* 24, 31-42.

Schultz P.W., Tabanico J. J. (2007) Self, Identity, and the Natural Environment: Exploring Implicit Connections With Nature. *Journal of Applied Social Psychology*, 2007, 37, 6, pp. 1219–1247.

Seamon, D. (1979). *A Geography of the lifeworld*. New York: St. Martin's.

Sengers P., Boehner K., David S., Kaye J., (2005). *Reflective design*. In Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility.

Shackel, B. (1959). Ergonomics for a Computer. *Design* 120:36–39.

Shackel, B. (1984). The concept of usability. In: J. Bennet, et al., (Eds) *Visual display terminals.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 45–88.

Shaer O., and Hornecker E. (2010). Tangible user interfaces: past, present, and future directions, *Foundations and Trends in Human-Computer Interaction* 3(1–2), 2-137.

Shannon, C. E. (1948). A Mathematical Theory of Communication, *The Bell System Technical Journal,* 27, 379–423, 623–656.

Sharma, R., Pavlovic, V. I., Huang, T. S. (1998). *Toward Multimodal Human-Computer Interface*. In Proceedings of the IEEE, 86(5), 853-869.

Sheryl Turkle, (2011), *Evocative Objects: Things we Think with*. Cambridge: MIT Press.

Simon H. A. (1996). *The Science of Artificial*. Cambridge: MIT press.

Sterling, B., (2005). *Shaping Things*. Cambridge: MIT press.

Suchman, L. A. (1987). *Plans and situated actions: the problem of human-machine communication*. Cambridge: Cambridge University press.

Tao Dong, (2015), *Designing Reflective User Experience with Social and Ubiquitous Computing Technologies*, PhD thesis University of Michigan.

Taylor, A. (2015) After interaction. *interactions* 22(5), 48-53. ACM.

Tuan Y.F. (1977) *Space and Place: Humanistic perspective*. In S. Gale and G. Olsson (Eds.), Philosophy in geography, pp. 387-427.

Van Egmond, R. (2008). The experience of product sounds. In H. N. J. Schifferstein & P. Hekkert (Eds.), *Product experience* (pp. 69-89). Amsterdam, the Netherlands: Elsevier.

Vardouli, T., (2015). Making use: Attitudes to human-artifact engagements, *Design Studies* 41, 137-161.

Verbeek, P. P. (2006). Materializing morality design ethics and technological mediation. *Science, Technology & Human Values.* 31(3), 361-380.

Verplank, B. (2009) *Interaction Design Sketchbook*: *Frameworks for designing interactive products and systems*. https://ccrma.stanford.edu/courses/250a-fall-2004/IDSketchbok.pdf. Last access July 2 2016.

Visser, W. (2005). Designing as Construction of Representations: A Dynamic Viewpoint in Cognitive Design Research. *Human-Computer Interaction*, *21*(1), 103-152**.**

Vredenburg, K., Mao, J., Smith, P. W., Carey, T. (2002): *A survey of user-centered design practice.* In Proceedings of the ACM CHI' 02 Conference on Human Factors in Computing Systems Conference. pp. 471-478.

Weiser M., (1991). *The Computer for the Twenty-First Century*. Scientific American, 265(3), 94–104.

Weiser M., Brown S., (1996). *Designing Calm Technology*, Xerox PARC.

Wendel, S., (2014). *Designing for behavior change: Applying psychology and behavioral economics.* O'Reily Media, Sebastopol, CA, USA.

Wever, R., Kuijk, J. V., Boks, C. (2008). User- centred design for sustainable behavior. *International Journal of Sustainable Engineering* 1(1), 9-20.

Whittaker S., Terveen L., Nardi B., (2009). Let's Stop Pushing the Envelope and Start Addressing It: A Reference Task Agenda for HCI. *Human-Computer Interaction* 15(2-3), 75-106.

Wiberg, M. (2012). Landscapes, Long tails & Digital Materialities – Implications for Mobile HCI research, *International Journal of Mobile Human Computer Interaction*, 4(1).

Wiberg, M. (2018). *Materiality of Interaction, Notes on the Materials of Interaction Design*. MIT press.

Wiberg, M. & Zaslavsky, A. (2010). Landscaping Future Interaction: Special Issue on Mobile and Ubiquitous Multimedia, Guest Editors Introduction, *IEEE Multimedia*.

Wilson E. O. (1986). *Biophilia.* Harvard University Press.

Young A. L. (2015). *The role of accidental Self-Reflection in wearable camera research.* In proceedings of MobileHCI'15, pp 1062-1065. ACM.

Zimmerman J., Forlizzi J. (2007). *Research through design as a method for interaction design research in HCI.* In proceedings of CHI'07, pp 493-502. ACM.

Zuboff S. (1984). *In the age of the smart machine: the future of work and power*. New York: Basic books.

Zuckerman, O., Gal Oz A., (2014). Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards and social comparison for promoting physical activity. *Personal and Ubiquitous Computing* 18(7), 1705-1719.

References

Publications

This PhD dissertation contains eight papers. Each one of these papers contributes to a part of this dissertation.

Paper 1 is mostly about the factors that motivate me to pursue this research journey. In this short paper, we present a design concept for behaviour change, informing from environmental psychology and our implicit connection with nature. **Paper 2** and **3** are mostly methodological, so they were useful for me during writing the second chapter of this dissertation, although they are about different projects carried out with TIM (Telecom Italia Mobile). **Paper 4** and **5** are the results of the literature study about reflection, behaviour change and physical and smart objects. So, they contribute mostly to the chapter 3, about "Concept Defining".

Paper 6 and **7** are about the study of home environment and the concept of place. In particular, they deal about a design agenda designing for reflection, considering the relations between places, objects and activities. **Paper 8** is the result of the chapter about constructing theories. It contributes also to the chapter 5, "Concept Appropriating" and discussion chapter. In this paper, we suggest a relation approach to designing for IoT system by model different relationships between users and computing artifacts. Then through an analysis of the Sóle prototype, we draw a theoretical model for the relationship between user and a *Tool for Reflection* that can be used for future researches.

Paper 1:

Ghajargar M., Gargiulo E., Giannantonio R. (2015). *Mobile Awareness: design for connectedness*. In proceedings of MobileHCI'15, pp. 1038-1041. ACM.

Paper 2:

Ghajargar M., Mangano G., De Marco A., Giannantonio R. (2017). Design Thinking applied on data storage innovation: a case study. *The Design Journal*, 2(sup1) 3776-3788. Taylor and Francis.

Paper 3:

Ghajargar M. (2016). *Designing connected artifacts for domestic environment: Reflections on the design processes and methodologies,* National Forum of PhD students in Design, Venice, Italy.

Paper 4:

Ghajargar M., Wiberg M., (2018). Thinking with Interactive Artifacts: Reflection as a Concept for Design Outcomes. *Design Issues.* 34(2), 48-63. MIT press.

Paper 5:

Ghajargar M., De Marco A., Montagna F. (2017). *Wise Things: when smart objects stimulate reflection,* In proceeding of 11th IHCI conference, 233-238. IADIS.

Paper 6:

Ghajargar M., Wiberg M. (forthcoming- 2018). *Designing Things and Places for reflection, a design agenda for social IoT*. In Social Internet of Things (Eds.) Soro A., Bereton M., Roe P. Springer.

Paper 7:

Ghajargar M., (2017). Toward intelligent environments: Supporting reflection with smart objects in the home. *interactions*, 24(4): 60-62. ACM.

Paper 8:

Ghajargar M., Wiberg M., Stolterman E. (forthcoming- 2018). Designing IoT Systems that Support Reflection: A Relational Approach. *International Journal of Design.*

Mobile Awareness: Design for Connectedness

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Abstract
This article describes our ongoing research project about design for behavior change, which is facilitated by Ubiquitous Computing technologies. In particular in this paper we discuss the potentiality of mobile devices to facilitate the mobility behavior change among people who are currently living at Turin, Italy. To this aim we illustrate our conceptual design of a mobile game, which is designed to facilitate mobility behavior change.

Author Keywords
Connectedness; Sustainable Behavior; Ecological Thinking; Self-Awareness; Internet of Things; Persuasive Design

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces

Introduction
The theoretical construct of self-awareness[1] has been applied in different contexts, including the context of social psychology. We have been based our work on the

[1] Self-awareness refers to the capacity of becoming the object of one's own attention (Duval & Wicklund, 1972), that means one can perceive stimuli, during an event and consequently feel emotions, but self-awarness rise up when the person find the connections between stimuli, events and emotions.

The Survey:

This survey has formulated in 26 questions and it's been structured in four essential parts: the demographic and the building's physical characteristics questions, followed by questions about people's willingness of going through altruistic actions (e.g. participate in UNICEF, helping other people, etc.), their habits and behaviors regarding mobility, waste generation and consumption of goods, water, food and other products, followed by the auto-valuation questions, through which they were asked how they valuate themselves and their communities regarding sustainability and happiness and questions about perception of smart objects and services. We have collected by now 300 responses and this survey will remain active until July 1st 2015.

definition of self-awareness as the personal experience of social community, which is connected to different layers of the environment. Self-awareness is also connected to the self-empowerment, as the Riva's Positive Technology framework affirms [1]. Authors proposed a framework to classify technologies according to their effects on personal positive experience and on improving social integration and connectedness. The term "connectedness", in psychology describes the extent to which individuals consider themselves parts of the universe [2] and is defined as the extend individuals cognitively include natural ecosystems in their representation of selves, which is the principle of ecological thinking.

As an individual or group's level of connectedness directly affects their level of ecological thinking and correlates with their desires for adopting sustainable behaviors [3] in this project we intend to investigate the role of self-awareness for designing a mobile game application which affects ecological thinking among users. Consequently we expect this to foster the sustainable behaviors among users.

In other words, to foster sustainable behavior, people need to improve their level of self-awareness and ecological thinking [4]. For this purpose, mobile and Ubiquitous Computing technologies which have changed the way we perceive ourselves and also our connection to the environment, can help people to become more self-aware, which is very important to make better choices and change behaviors. [5], [6]

Research objectives

To address this issue, we need educational tools that develop the cognitive capacity of ecological thinking[2]. The education of sustainability is an area with high potential for application of this concept since it seeks to promote people's motivation and engagement [7], [8]. Through this paper we introduce the preliminary analysis and a conceptual design of a digital mobile instrument, which might help people to overcome the lack of self-awareness and shift from exclusive behaviors to more inclusive behaviors [2]. (Figure 5)

Methodology

An ongoing survey has been conducted online since April 22nd 2015, among people who are living in Piedmont region, which is the largest Italian region situated in northwest of Italy. The objective of this survey is evaluating and analyzing the level of ecological thinking and sustainable behaviors among people in order to design appropriate product and services, which would help to change, foster or maintain a certain behavior.

Due to the educational purpose of this project, we also need to use proper tools. We are planning to apply Gamification principles and Serious Games tools, which is a concept intending to use elements and processes from real games into non-games applications. We will apply this tool to improve user's self-reflection skills, in order to understand the relation between them and their social and natural environments. An example of

[2] Ecological thinking is the ability to understand the whole world, including natural elements, humans and artificial elements, as a highly interconnected mesh.

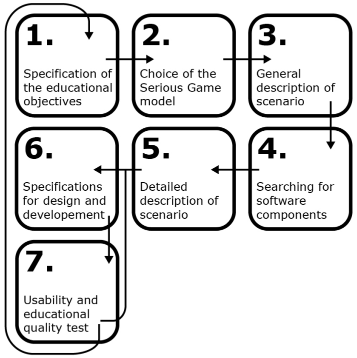

Figure 1: The seven steps for designing Serious Games [7], revised by authors.

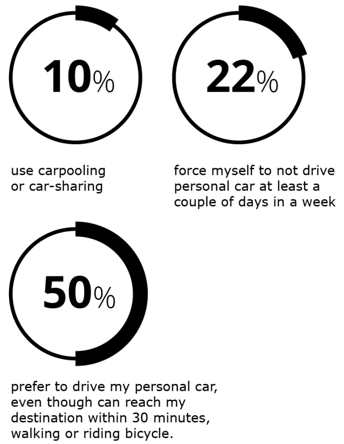

Figure 2: Their attitudes towards mobility (Results of the survey)

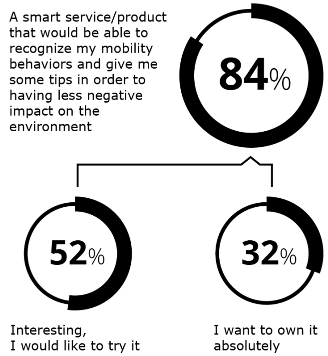

Figure 3: Their tendency to use appropriate smart object and service in order to recognize their habits and assist them to change their mobility behaviors (Results of the survey)

the steps for designing an educational game is reported. [7] (Figure 1)

Partial results and conclusions

We have analyzed the survey partially, and we understood that while the most part of the respondents (65%-85%) concerns about the sustainable energy consumption and also waste recycling (80%-90%), they pay less attention regarding the sustainable mobility behaviors, (Figure 2). Also it has been identified that they have tendency to use appropriate smart object and service in order to recognize their habits and assist them to change their mobility behaviors, (Figure 3) and is evident that they are aware of the role they can play on environmental and social sustainability. (Figure 4)

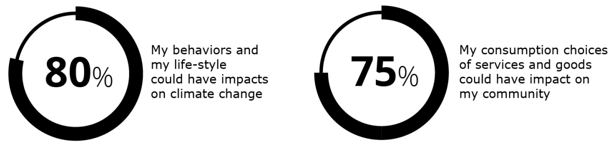

Figure 4: Their willingness to change behavior (Results of the survey)

On the result of this analysis we have decided to design a mobile game through which, user will interact with personal informatics [5]. By personal informatics we mean an activity by which people collect and reflect on personal data to gain better understanding of their own behaviors. Personal informatics tools can vary among websites, mobile devices like a smartphone, etc. among those, we have chosen the smartphone. We chose smartphone, because it's considered the symbol of "personal digital life", which is although a personal mobile device but it also broadens the boundary beyond the personal life, towards family life and even to the city mobility life.

1	**Collect data:** Through user's self-declaration
2	**Learn:** User's mobility behaviors
3	**Suggest:** Appropriate action
4	**Assist:** During the process of behavior change
5	**Engage:** Through Gamification
6	**Give awareness:** About the effects of user's actions

Table 1. The six main functions of the mobile game

This mobile game application will consist of three fundamental sections of "My Self", "My Community", and "My Planet" which are graphically presented as three circles on the mobile interface. The area of "My Self" collects information regarding personal wellbeing and economy. For this area we focus on collection of personal data for the purpose of gaining insights and understanding of oneself. The data can be both qualitative (e.g. moods) and quantitative (e.g. heart rate). The area of "My Community" regards the contagiousness of one's actions. This will explain how the user's daily choices affect the choices made by user's community. This area also concerns about the relations of the user with the community, whether real or virtual. (e.g. social networks) Finally the area of "My Planet" demonstrates the effects of personal choices on planet's heath and environmental sustainability.

Sketches and expected outcome

The graphical language of the user interface (Figure 6) recalls the Schultz's integrated cognitive representation of self and other. (Figure 5)

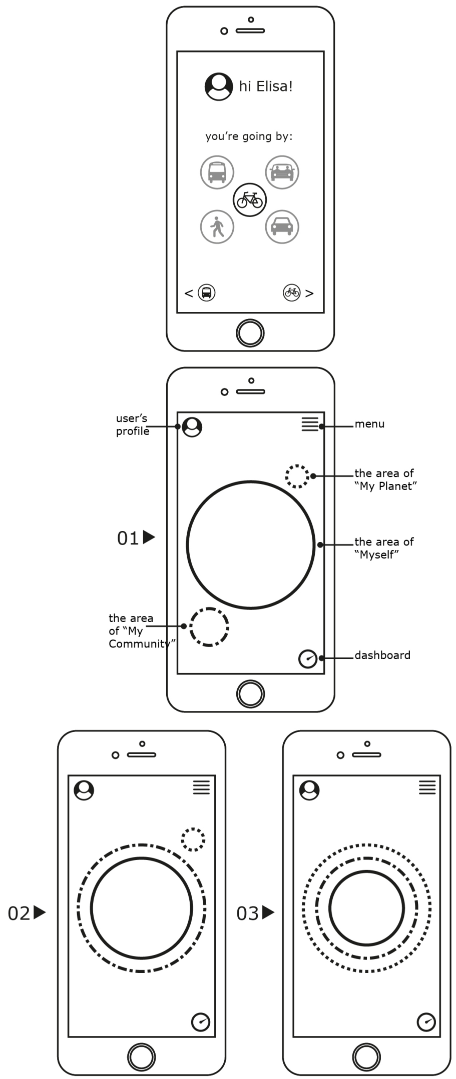

Figure 6: Sketches of mobile game interface.

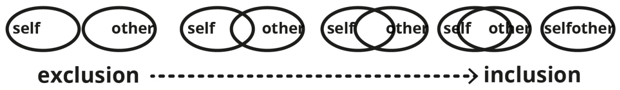

Figure 5: Schultz's integrated cognitive representation of self and other, 2001.

Future steps

We will conclude the data collection from survey in order to have guidance on design process, and then will analyze the results through focus groups and co-design sessions, conducted among the target emerged from the survey. For co-design sessions we will use appropriate participatory design tools and then we will build a low fidelity and navigable prototype to conduct usability test with users. This mobile game application is expected to be connected also to other designed smart objects at home environment in order to be able to learn all other behaviors which is related to interact with tangible artifacts. (e.g. smart key holder.)

References

1. Riva Giuseppe et al. "Positive Technology: Using Interactive Technologies to Promote Positive Functioning", cyber psychology, behavior, and social networking Volume 15, Number 2, 2012
2. Schultz, P.W. "The structure of environmental concern. Concern for self, other people, and the biosphere", Environmental Psychology, Vol. 21, 2001
3. César Tapia Fonllem, et, al. "Assessing Sustainable Behavior and its Correlates: A Measure of Pro-Ecological, Frugal, Altruistic and Equitable Actions". Sustainability, Vol. 5, 2013
4. Victor Corral-Verdugo et. al, "Happiness as Correlate of Sustainable Behavior: A Study of Pro-Ecological, Frugal, Equitable and Altruistic Actions That Promote Subjective Wellbeing", Human Ecology Review, Vol. 18, No. 2, 2011
5. Ian Li, Anind K. Dey, Jodi Forlizzi1, "Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies", UbiComp, Beijing, China, 2011
6. BJ Fogg, "A behavior model for persuasive design", Proceedings of the 4th International Conference on Persuasive Technology - Persuasive '09, Claremont, USA, 2009
7. Iza Marfisi-Schottman, Sébastien George, Franck Tarpin-Bernard, "Tools and Methods for Efficiently Designing Serious Games", ECGBL, Copenhagen, Denmark, 2010
8. Morin Alan, "Self-Awareness Part 1: Definition, Measures, Effects, Functions, and Antecedents". Social and Personality Psychology Compass Vol. 5 2011
9. Deterding, S., Dixon, D., Khaled, R., & Nacke, L. "From game design elements to gamefulness: Defining "Gamification"". Proceedings of MindTrek, 2011
10. Bandura, Albert, "Social Learning Theory", Prentice Hall, Englewood Cliffs, NJ, 1977
11. Bandura, Albert, "Social Foundations of Thought and Action", Prentice Hall, Englewood Cliffs, NJ, 1986

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Design Thinking Applied to Data Storage Innovation: A Case Study

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Abstract: This paper presents part of a larger study that seeks to investigate the potential of the Design Thinking (DT) approach when applied to innovation processes especially on product and service development in the ICT industry. In particular, the DT approach is applied to the case study of a backup and storage service as a distributed, fog-computing infrastructure. Its functionality is based on sharing the available disk storage of personal and organizational devices.
The case study presents the process of applying the DT approach and the way this can contribute not just to improve the solution in terms of customer desirability and market viability, but also the collaborative way of current technological design process. In particular, the DT approach, apparently hard, fuzzy and time consuming during the initial steps of the design process, proved successful in studying the relationship between the value propositions and the target clients of the innovative data storage service.
A first co-design session helped to understand that the most important features enabled by the fog-computing paradigm, such as data security and privacy could be more valuable for a corporate context; thus the proposed solution shifted to a Business-to-Business (B2B) model. Other co-design sessions helped better understanding the service value proposition and final users.

Keywords: Design Thinking; Design Process; Data Storage Innovation

1. Introduction

Historically, the design activity considered one of the last steps in an innovation or product development process; a down-stream activity focused on improving the appeal of a product just prior to launch to the market.

Today, however, more and more organizations are pulling the design activity further upstream, applying Design Thinking (DT), as a way to employ the designers' skills, toolkits and also mindsets (Cross, Dorst and Roozenburg, 1992, Johansson and Woodilla, 2009) to help create solutions to complex problems or to build processes and systems able to optimize the outcomes (Shannon et al., 2015). Design thinking is an interdisciplinary, participative and human-centered approach. It seeks to involve all stakeholders affected by the product or service, since the early stages of design process.

Furthermore, it emphasizes the iteration way of problem solving instead of the linear way. It allows finding the solution in diverse fields of application, especially where there is a complex problem. By gathering information from potential users, stakeholders and the field studies, project team iteratively change and improve a product or a service. Doing so by using different tools and methods such as co-design sessions, customer journey, stakeholder mapping, field studies, survey, interviews, market analysis and many others throughout the DT process.

The objective of this paper is to present the application of the DT methodology to design and develop an innovative data storage service. In particular, here we present a project, which has been conducted at TIM Joint Open Lab, in collaboration with ISMB [1].

Although the case study, originated from a technology-push approach – which stands for designing products *for* the existing technology – we applied DT, in order to challenge and modify the existing design approach towards a human-centered approach – which stands for designing *with* technology, or design *of* technology.

In particular, the new data storage service is enabled by fog-computing. The Fog-computing paradigm, which inspires from the collaborative economy principles, is a decentralized computing infrastructure, which permits to share available and idle computing resources within a network of connected devises. Collaborative or sharing economy helps to create a sustainable value chain among different stakeholders, saving costs and reduce the environmental impacts (Puschmann & Alt, 2016, Botsman & Roos, 2011). In collaborative economy the focus shifts from offering a stand-alone product, to creating services that enable people to make the most of the resources around them. Fog Computing can enable the collaborative economy through sharing the distributed and available computing resources among different devices and clients.

In fact, fog computing is becoming a promising technology for data storage. This new technology proves to be more efficient compared to cloud computing as long as it reduces the amount of data moved to the cloud in order to process, analyze and store. Although fog computing is often used to increase data storage efficiency, it can also enhance data security and privacy thanks to data encryption.

The paper is structured as follows. After a brief introduction to the Design Thinking methodology, we present the existing method already applied to the technological design process in Swarm Joint Open Lab. Then the new methodological approach, which is inspired by DT will be presented and finally, we present and discuss the main results and track future research steps.

2. Background

Design Thinking approach in literature has been defined both as a fuzzy, and analytical process for problem solving in business, learning, health and organizational contexts among others. However, there seems to be a common point of view with respect to Design Thinking as a process applicable to the involvement of both analytical and experimental studies (Simon, 1969, Rylander 2009). The Design Thinking can provide a powerful way to interact (Teal, 2010) and may even go beyond the limits of imagination and overcome innovation barriers (Buchanan, 1992).

DT as a process in literature has been defined as an iterative, collaborative and human-centered process. It contains usually four essential phases during the process: empathizing with end-user,

[1] Istituto Superiore Mario Boella (ISMB)

defining needs and problems, ideate and build solutions and iterate to test and improve the solution (Brown, 2009).

Empathizing with end-user in particular, helps designer and developers to fully understand and define the end-users' needs and problems. The designer's perception regarding user's needs and its requirements helps to develop effective alternative solutions. Thus, designers manage different group of people in order to define and identify the alternative means to address needs and to achieve the expected results. Finally, the process enters in an iterative prototyping and testing phase in which different concepts will put into action (Roberts et al., 2015). The key element of DT approach prescribes a human-centered and collaborative way of addressing a problem by taking "people first" (Erzurumlu and Erzurumlu, 2015). In this way, mostly all stakeholders are involved and so able to take into account all relevant aspects that could inspire and improve (Brown and Wyatt, 2010). This approach sometime is based on four crucial questions namely: What is? What if? What wows? And what works? (Liedtka, King and Bennett, 2013). Each question explores a different stage of the DT process.

'What is' explores and examines the current situation or the state of the problem, also concerns about a detailed and in depth exploration of all internal and external factors that might have caused it. This phase considers the factors that caused the problem in a very broad context, rather that just focusing on the close context. 'What if' analyzes and applies the lessons learnt during the first stage to diverge to as many alternatives as possible and consequently to converge to the definition of achievable solutions. 'What wows' supports managers in the choice of what has been selected in the previous stage according to the market viability and technological feasibility of the solution. In the 'What works' stage, team create prototypes and test them with the real users of the selected solution (Liedtka, 2014).

DT uses particular tools to support the collaborative and iterative nature of the process such as co-creation, user-journey and field studies. During the whole process it also uses visualization methods such as drawings, diagrams, sketches, video clips, and photos in order to create a responsive environment able to generate empathy and creativity among the team members (Halloway, 2009).

The DT application is more helpful and advantageous during the early stages in an innovation process, whereas problems are not well defined yet. It is becoming more and more appealing because it brings the design to its essence, it is able to bridge the gap between theoretical knowledge and practice in design, promote comprehensive and collaborative ways of thinking and it is applicable in many disciplines such as management, operation research, social innovation, logistics, etc. (Katoppo and Sudradjat, 2015). The unique nature of DT as a collaborative, creative, and human-centered instead of technology-centered methodology has a huge potential within business organizations. It supports them as they face challenges and complex problems and it is able to bring intrinsic values to enhance organizational life (Shannon et al., 2015, Clark and Smith, 2008). Design Thinking as a powerful tool to transform business and organizations has been the subject of many researches. As companies grow in number of employees and projects, they require more effective problem solving methods able to tackle the complex and unknown problems (e.g. Brown, 2009; Martin, 2009; Lockwood, 2010; Cross, 2011; Liedtka & Ogilvie, 2011). Some large sized companies such as IBM and GE have already realized that although the software development is a fundamental part of their businesses; they also need to manage the extraordinary levels of complexity that it might bring. As long as DT is an essential tool for simplifying and humanizing, thus they have realized that it can't be an extra in organization rather it needs to be a core competence (Kolko, 2015). DT can be used to innovate and solve problems across many professions, and this brought design process itself into significant conversations and decisions that shape the collective future in the business world (Clark and Smith, 2008).

In particular DT has become appealing for business innovation in organizations, taking inspiration from the way designers work to broaden their repertoire of strategies for addressing the complex and open-ended challenges (Martin, 2009).

3. A Case Study

3.1 The Current Design Process

To understand the current state of design process, we first conducted a series of interviews with three main open-ended questions among six professionals who are currently involved in different stages of the design process in Swarm Join Open Lab. Our sample consists of a Telecommunication engineer (male, 39 YO), a computer scientist (male, 43 YO), a software engineer (male, 42 YO), two psychologist and user experience specialists (UX) (female, 33 and 31 YO), and a junior graphic designer (female 25 YO).

On the basis of the results of the analysis of the interviews, it is evident that the design process mainly consists of six phases. First, they receive a brief, requesting the development of a new technology, and then the technical team develops the new technology on the basis of available resources. Then, a concept idea will be generated, principally through running short brainstorming sessions among the technical team members.

At that point, the team develops a demo or proof of concept and then test it along with user study specialists and end-users. To this aim, a user study consultant team, run questionnaire and usability tests, in order to understand not only the technical functionality, but also the efficiency and performance of the demo. The demo then will be again tested through running a field trial testing and validation. This step consists of testing the demo among a group of pilot users in a real context, which could vary from home environment to work spaces, depending on the target context of the project.

After testing the concept, on the basis of the received feedbacks from end-users or trial users, the demo will be improved and refined and again tested through an iterative process loop. When the concept is ready in terms of the functionality and usability, the process can continue in two distinctive and sometime parallel directions: whether to submit the product as a patent if it is eligible, or follows by the conduction of the market and deeper end user analysis. Joint Open Lab does not usually conduct this phase, and it consists of conducting further questionnaires and focus groups in order to understand how this new technology can facilitate the design of a new service or product.

Then, if applicable, they go through business modeling and planning. The focus groups in particular serve for understanding and testing the feasibility of the potential service or product among homogeneous experienced professional group who have expertise in a particular field related to the service or product prior to lunch to the market. (Figure 1)

3.2 The Design Thinking Process

Although the solutions ideated previously were technologically innovative and mostly patent eligible, they face some problems regarding the product’s desirability among people and the market viability.

As an attempt to overcome these difficulties, we involved not only the end users, but also the designers in the project team since the early stages of design process.

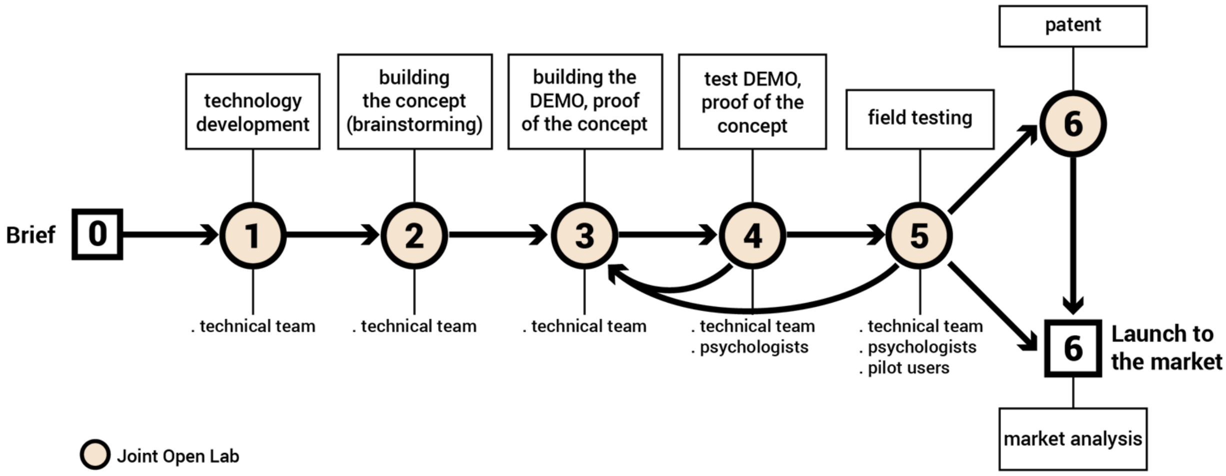

Figure 1: the current technological design process in Swarm Joint open Lab

As an experiment to improve the design process, the DT approach has been applied to a new project, which develops a distributed data storage service based on fog-computing technologies.

We have started the project with a first hypothesis, assuming that people are concerned mostly about the privacy of their personal data, when they choose to use a new data storage service. Therefore, users would be interested to adopt an innovative technological service, which addresses this issue. In order to validate this first hypothesis, the DT process and steps have been set within an interdisciplinary group consisting of technical staff and a design researcher. The DT process applied to this project consists of seven main phases (Figure 2).

I) To empathize with people who are mostly affected by the service: we did this through two co-design sessions, the first one has been conducted among end-users who had previously answered to a very short questionnaire on their habits regarding the frequency and quality of data storage service usage; the second co-design session has been conducted among IT mangers of five big companies and institutions;

II) To analyze user needs and to define suitable service value propositions. User needs and service value propositions have been defined mostly through designing a business model, using Business Model Canvas and Value Proposition Design tools, based on the most important value propositions emerged mostly from the second co-design session (Osterwalder and Pigneur, 2010, Osterwalder, et. al., 2014);

III) To conduct a market analysis, by exploring the current services, which are already available in the market, understanding their value propositions, target clients and the service specifications;

IV) To ideate alternative solutions, to evaluate the solutions and to select the most feasible, viable and desirable alternative, doing this through another co-design session, involving designers, technical team and marketing specialists.

V) Prototyping the selected solution;

VI) To conduct field tests with pilot-users;

VII) Submit a patent, if eligible, and/or launch to the market

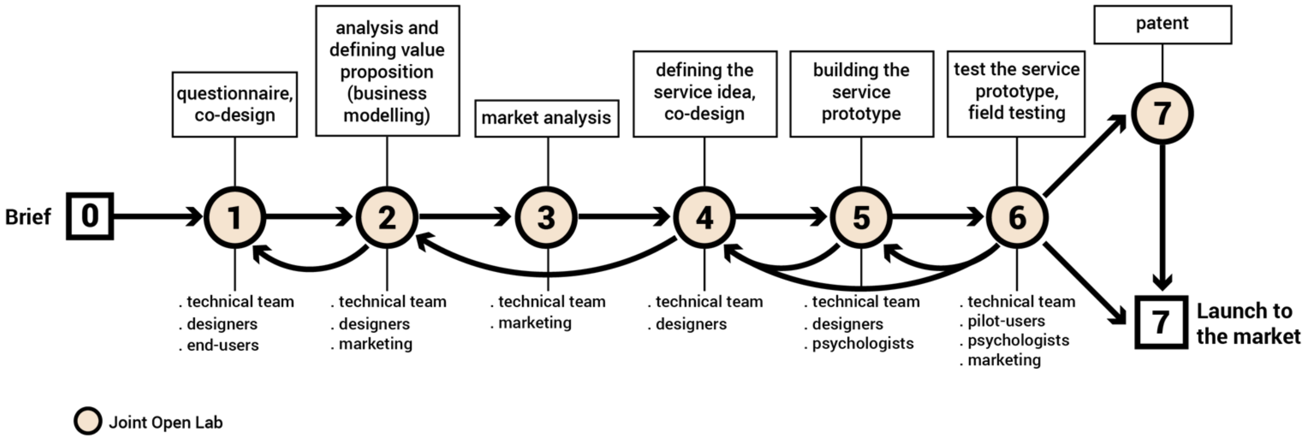

Figure 2: the design thinking process

3.3 The first co-design session with end-users

A multidisciplinary group has been created to follow this project, involving people from Joint Open Lab. The group consists of telecommunication, software and management engineers, a design researcher, a graphic designer, mathematicians and operation researchers.

Soon after the group formed, a co-design session has been conducted among twenty heterogeneous participants. The main objective of this session was to uncover underlying needs and issues regarding usage of data storage service. Prior to the session, participants had answered a short survey about their habits regarding the usage of a sample of existing data storage services. The sample consists of nine women and eleven men (Male: 55%, Female: 45%), who mostly use Google Drive and Dropbox as free data storage services (84%). They wish to have a data storage service, which is free of charge and apparently those services can meet this particular need (84%). Most of them use and log into the data storage services through personal computers applications (92%), through mobile devices applications (63%) or through logging in through the service website directly (60%).

Along with the questionnaire, a brief had been also emailed to the potential participants, explaining the purpose of the co-design session and the key design concepts (e.g. taking advantage of the increased capability of data storage thanks to the resources which are distributed among different devices connected to the Internet, etc.).

The co-design session comprised of five main divergent and convergent steps as follows: empathize, define, ideate, iterate and conclusion, which are the main phases of the design thinking process (Plattner, Meinel, Leifer, 2010).

The main objective of this workshop was to understand better users' concerns, problems and needs regarding data storage services, even though, participants have been also encouraged to participate for service concepts ideation.

Participants have been distributed in 10 couples in total of 20 participants (Figure 3, 4, 5). In particular, this sample has been selected from Politecnico di Torino's students (Undergraduate and graduate levels) and Joint Open Labs' and Mario Boella Institute's employees.

Figure 3: the 3rd phase of the session: "ideate"

The session took long about two hours, including two short presentations regarding the project objectives and the brief. Three researchers observed and facilitated the process during the whole session. Participants during each step had a limited time to complete a particular assignment. The process involved both individual and in team working, depending on the objective and the nature of the phase. The individual works mostly concerned about the reflection, observation and decision-making, while the task conducted in team, concerned about the evaluation, correspondence and comparison. A more detailed description of the five phases of the session is brought in Table 1.

Table 1: co-design session phases: detailed description

Phases	What (process)	How (tasks)	Why (purpose)	Duration (minutes)
I) Empathise	**Diverge**	**Interview-Writing**	**Understanding: User-experience**	**16**
II) Define	**Converge (De-briefing)**	**Observing-Writing**	**Reflecting: Issues, needs and desires**	**12**
III) Ideate	**Diverge**	**Sketching, visualizing**	**Finding solutions**	**12**
IV) Iterate	**Converge (Decision making)**	**Interview-writing**	**Choosing the best solution; Proofing the idea**	**5**
V) Conclude	**Converge (Decision making)**	**Writing**	**Reflecting, Choosing: enabler technology Cloud or Fog computing?**	**2**

3.4 Result of the first co-design session

After analyzing the output of the session, we have identified six main categories of user needs, which have been emerged during the first phase and interviews.

The user needs categories are mainly related to: 1) access and login procedures to the data storage service; 2) collaborative activities; 3) actions required for sharing files among collaborators; 4) the software performance and the degree of data security and privacy. We categorized these needs in two distinguished interactional levels. While the first level concerns about the issues that occur while user and service interact (Level 01: User-Service Interaction), the second level concerns about the issues occurring while user, service and the network (collaborators) interact together (Level 02: User – Service – Network Interaction). (Table 2)

Figure 4: the 1st phase of the session: "empathize"

Figure 5: the 2nd phase of the session: "define"

The results of the first co-design session showed that data security and data privacy, which are the most important features, enabled by the fog-computing paradigm, could be more valuable for big companies rather than end-consumers. However, the result of the first co-design session will be applied on the design of the data storage service, we made the second hypothesis and we shifted the business model from business to consumer (B2C) to the business to business (B2B).

Table 2: the six categories of needs in two levels of interaction

	Category	Needs
User – service interaction	**I) Login/Access**	**Simplicity**
		Duration login
		Direct access
		Search ability
	II) Performance	**Synch**
		Upload
	III) Security	**Data privacy**
	IV) Storage	**Back-up**
		Free space
User- Service- Network Interaction	**I) Collaboration**	**Conflict management**
		Editing simultaneously
		Organizing
		Communicating
		Sharing
	II) Sharing	**Preventing errors**

3.5 The second co-design session with IT-managers

In order to identify the big companies' requirements and then define the service specifications, another co-design session with IT managers of big public and private companies and institutions has been held (Figure 6). As far as the number of available devices able to connect to the Internet concerns, each company owns more than 4,000 personal computers, both laptops and desktop computers, employees often use also smartphones and tablets. The preliminary questions associated with the current situation, highlight that the solution selected for the back up of the data exploits servers and it offers more than 100 GB. This solution is generally described as easy to use, safe, and quick. The amount of space available usually has been considered as "not enough". Therefore, according to calculation of the total available data storage (PCs, smartphones, tablets), this new service is able to offer more space to share files and documents without creating congestion and impacting negatively the speed of the system. In addition, the privacy and the security are always guaranteed thanks to the data encryption enabled by fog-computing paradigm.

3.6 Results of the second co-design session with IT managers

The analysis of the second co-design workshop showed, IT managers are principally satisfied with their current data storage service in terms of efficiency and effectiveness. Despite it shows that current services mostly address the company's requirements, they are willing to test and if necessary, adopt the new data storage service if only it can offer values in terms of real cost saving, the increase of available space, data privacy and environmental sustainability.

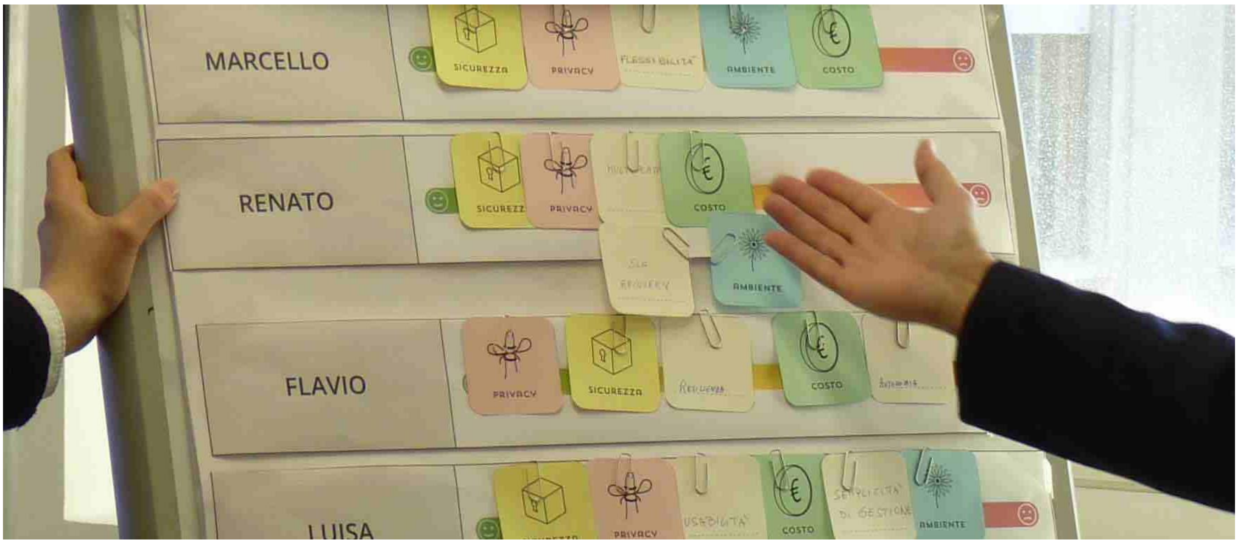

Figure 6: the 2nd co-design workshop: participants discuss about the most important values that service could offer, choosing among value proposition cards.

4. Market research: data storage services

The market analysis involved seventeen main companies that offer data storage services with different related features and different business models- i.e. Business to Customer (B2C), Business to Business (B2B), or both (B2B2C).

Each company has been analyzed through an evaluation sheet. This sheet takes into account the value proposition, the type of service that is offered, the key resources, the functionalities of the service, the eventual external financing and the price.

Each service's value proposition refers to a specific customer or business segment. The type of service is closely related to the technology used for developing and managing the service, the key resources represent the resources, in terms of materials, staff, and other assets required to develop, advertise and sell the service. The service functionalities represent the features offered by the service that address the customer's needs. The external financing considers eventual external financial resources such as venture capital, and the pricing strategies shows the different services packages, which are offered by the company.

Currently all companies under examination, offer data storage services based on Cloud-Computing or local servers.

The most important service features are the possibility to create multiple accounts; the management of multiple devices and along with a customer care assistance service. The price often depends on the service package and the customer requirements, thus it can be adapted and personalised according to the specific customer need.

This short market analysis proved that data storage services available in market run on Cloud-Computing technology mostly, and the most important value that they offer is the data privacy and the extra free space, which they seek constantly to improve.

5. Conclusion and future steps

The case study presented throughout this work illustrated the process of the Design Thinking methodological approach applied to an innovative data storage service up to the market analysis stage. Another four steps will follow in order to ideate and improve the technological features and the business model before launching to the market (Figure 2). In particular, this experiment, has shown that the DT approach, even apparently time consuming and blurry during the initial steps of the design process, it proved successful in studying the relationship between the value proposition and the target clients of the service. In fact, the two co-design workshops helped to pivoting and iterating in order to find out the real service’s value propositions for people who will use it. It was also helpful in understanding of why people might use it and even if really people want or need those kind of services.

The application of DT methodological approach itself faced some difficulties. This was mostly due to the lack of previous attempts and experiences regarding application of this approach. Other factors such as organizational constraints and limitations of the resources caused also frustration moments. This experiment is an example, where for the first times involves designer as a professional practitioner since the very early phases of technological design process, yet proved difficulties and uncertainty to understand the leadership role of design. For instance, technical team members could not understand what is the role of the designer, who is a professional figure that works on the aesthetical aspects of a product. User Experience specialists, on the other hand could not accept the role of the designer in studying the user needs. In short why a designer that shapes the forms of the ultimate product, should be involved since the early stages of technological process, when the product idea is not still clearly defined. Other issues were for instance the difficulty to communicate in an interdisciplinary context where has been for many years dominated by people from technical backgrounds.

In some points, during the process, the DT method seemed as a vague, blurry and very broad approach, however the collaborative and human centered nature of this method has been appreciated among technical team members. In fact, the whole DT process comprised regular moments of collective thinking and decision making. Those moments helped to improve the product constantly, to anticipate the needs for further development. They also improved the communication process among interdisciplinary team members in general and more particularly they helped to develop a “common language” with which team members increasingly improved the way they communicate to each other.

This work can contribute to the future studies regarding not only the application of the DT methodology on digital service innovation but also the way, through which it might improve the collaborative process of design. In fact, this process showed an effective way to involve actively the collaborators from different disciplines who had not been before able to work together. However, in order to validate the collaborative fashion of DT approach, and the way this approach have fostered the collaboration and participation among team members, further analysis is needed and it can be conducted through empirical and field studies upon the project has been completed.

References

Botsman, R. and Roger, R. (2011). What's Mine Is Yours: How Collaborative Consumption is Changing the Way We Live. *HarperCollins Business*.

Brown, T. and Wyatt, J. (2010). Design thinking for social innovation, *Stanford Social Innovation Review, Vol. 8 No.1, pp. 30-35.*

Buchanan, R. (1998). The Study of Design: Doctoral Education and Research in a New Field of Inquiry. *Doctoral Education in Design: Proceedings of the Ohio Conference, October 8-11, 1998*, (1998).

Clark K. and Smith R. (2008), Unleashing the Power of Design Thinking, *Design Management Review.*

Cross, N., Dorst, K., and Roozenburg, N. (1992). Preface to Research in Design Thinking. In N. Cross, N., Dorst, K., Roozenburg, ed., *Research in Design Thinking*. Delft University Press, Delft.

Erzurumlu, S.S. and Erzurumlu, Y.O. (2015). Sustainable mining development with community using design thinking and multi-criteria decision analysis, *Resources Policy, Vol. 46 No. 1, pp.6-14.*

Halloway, M. (2009). How tangible is your strategy? How design thinking can turn your strategy into reality? *Journal of Business Strategy*, Vol. 30 N.2/3, pp. 50-56.

Johansson, U. and Woodilla, J. (2009). Towards and epistemological merger of design thinking, strategy and innovation. *In the proceedings of 8th European Academy of Design Conference.*

Katoppo, M.L. and Sudradjat, I. (2015). Combining Participatory Action Research (PAR) and Design Thinking (DT) as alternative research method in architecture, *Procedia – Social and Behavioral Sciences, Vol. 184 No. 20, pp. 118-125.*

Kolko J. (2015). Design Thinking Comes of Age, *Harvard Business Review, September Issue.*

Liedtka, J. (2014). Innovative ways companies are using design thinking, *Strategy & Leadership*, Vol. 42 No.2, pp. 40-45.

Lindberg, T., Gumienny, R., Jobst, B., and Meinel, C. (2010). Is There a Need for a Design Thinking Process? *Design Thinking Research Symposium 8*.

Martin, R., (2009), The design of business. *Cambridge MA: Harvard Business Press.*

Norman, D.A. (2013). The Design of Everyday Things, *Revised and Expanded Edition. MIT Press, London.*

Plattner H., Meinel C., Leifer L. (2010). Design Thinking: Understand, Improve, Apply. *Springer*

Puschmann, T., Alt, R. (2016). Sharing Economy, in: Business & Information Systems Engineering, 58, 1, pp. 93-99

Roberts, J. P., Fisher, T.R., Trowbridge, M.J. and Bent, C. (2015). A design thinking framework for healthcare management and innovation, *Healthcare*.

Shannon, E. Connell, F. and Tenkasi, R.V. (2015). Operational practices and archetypes of design thinking, *Research in Organizational Change and Development*, *Vol.23, pp. 195-252.*

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Progettazione di manufatti connessi per l'ambiente domestico: riflessioni sui processi di progettazione e metodologie

Maliheh Ghajargar Politecnico di Torino

1. *Introduzione*

Il crescente utilizzo di tecnologie informatiche e la connettività a Internet hanno portato enormi cambiamenti nel modo in cui le persone vivono, lavorano, si divertono e interagiscono tra loro. Questo fenomeno viene descritto con vari nomi: *Ubiquitous Computing*[1], *Internet of Things*[2], *Connected Homes*[3], *Living Services*[4] ecc.

Quest'articolo presenta una parte di uno studio più ampio, volto a indagare le prospettive di una nuova metodologia per progettare gli artefatti tecnologici e connessi pensati per l'ambiente domestico. Questi artefatti sono in grado di rilevare le azioni umane con lo scopo di monitoraggio, verifica e rilevazione di pattern di queste azioni, e di fornire una valutazione. L'articolo è diviso in due parti principali, la prima offre una panoramica della letteratura esistente, riguardante la progettazione tecnologica per l'ambiente domestico, al fine di fornire un'analisi dei fattori più importanti per la progettazione tecnologica per la casa, nonché una breve introduzione di due delle metodologie principali del design applicate al contesto tecnologico. La seconda parte, invece, è il risultato di una serie di interviste semi-strutturate, condotte su tre diversi gruppi di persone/professionisti che afferiscono a discipline diverse, tutte in qualche modo coinvolte nel processo della progettazione di artefatti tecnologici per l'ambiente domestico: ingegneri informatici, designer e specialisti di UX (*User Experience*).

Infine, si discuteranno le direzioni di ricerca future (la necessità di sviluppare un nuovo linguaggio di comunicazione tra diverse discipline).

2. *Background*

La crescita della connettività a Internet ha portato a un crescente interesse per l'utilizzo delle tecnologie informatiche in ambiente domestico. Questo mette in luce tale ambiente come il sito potenziale del consumo di manufatti tecnologici da parte dei produttori di tecnologie dell'informazione e della comunicazione[5]. Negli anni Novanta è emersa la necessità di una comprensione più profonda della natura di quest'ambiente, in quanto contesto d'uso di artefatti tecnologici: precedentemente

[1] M. Weiser, R. Gold, J.S. Brown, *The Origins of Ubiquitous Computing Research at PARC in the Late 1980s*, «IBM Systems Journal», 38, 4, 1999, pp. 693-696.

[2] K. Ashton, *That "Internet of Things" Thing, in the Real World Things Matter More than Ideas,* «RFID Journal», 2009, www.rfidjournal.com/article/print/4986.

[3] *Connected Homes: An Ericsson Consumer Insight Summary Report,* Stockholm, Ericsson ConsumerLab, 2015, https://www.ericsson.com/res/docs/2015/consumerlab/ericsson-consumerlab-connected-homes.pdf.

[4] *The Era of Living Services*, London, Fjordnet Ltd, 2014, https://livingservices.fjordnet.com/media-files/2015/09/living-services.pdf.

[5] A. Venkatesh, *Computers and Other Interactive Technologies for Home*, «Communications of the ACM», 39, 12, 1996, pp. 47-54.

i sistemi e prodotti altamente tecnologici erano stati progettati esclusivamente per l'ambiente del lavoro, che differisce (di molto) dall'ambiente domestico. Il rapporto tra contesto tecnico – dove la tecnologia viene usata – e quello sociale – dove le attività giornaliere della casa accadono – dell'ambiente domestico è stato l'obiettivo di molte ricerche scientifiche[6].

La collaborazione e la cooperazione sono in gran parte considerate in letteratura come caratteristiche endemiche dell'ambiente domestico, analogamente agli spazi, che sono socialmente organizzati. A causa di questa proprietà, le ricerche condotte nell'ambito dell'HCI *(Human-Computer Interaction)* presentano un forte interesse a sviluppare le nuove forme d'interazione che si possono ottenere, integrando la tecnologia informatica con il mondo fisico di tutti i giorni in cui viviamo e lavoriamo[7].

2.1 *Progettazione tecnologica per l'ambiente domestico*

Negli ultimi due decenni sono stati condotti molti studi che dimostrano come gli utenti adottino la tecnologia in modi sorprendenti e imprevedibili. La maggior parte di questi si è concentrata sulle tecnologie da ufficio, che sono notevolmente differenti rispetto alle tecnologie per la casa[8]. Abowd e Mynatt[9] dimostrano la necessità di condurre studi più approfonditi degli ambienti domestici per informare il design.

In questa sezione vorremmo riportare alcuni contributi della letteratura più rilevanti per quanto riguarda lo studio della casa come uno spazio socialmente organizzato e un ambiente per applicare le tecnologie informatiche. L'obiettivo delle numerose ricerche scientifiche condotte in quest'area è considerare il concetto di gestione del tempo e il risparmio economico, nonché l'impatto sul ruolo delle donne in casa. Tra la letteratura sulle tecnologie per la casa si distingue la rigorosa ricerca di Venkatesh[10] sull'*Home Computing*. L'*Home Computing* è emerso dal boom di *microcomputer* nel 1980. Venkatesh per la prima volta ha studiato la relazione tra la casa

[6] Si vedano a tal proposito R. Bentley, J.A. Hughes, D. Randall, T. Rodden, P. Sawyer, D. Shapiro, I. Sommerville, *Ethnographically-informed Systems Design for Air Traffic Control,* in *CSCW 1992: Computer Supported Cooperative Work*, atti del convegno (Toronto, 1-4 novembre 1992), New York, ACM,1992; G. Button, W. Sharrock, *Occasioned Practices in the Work of Software Engineers*, in M. Jorotka, J.A. Goguen (a cura di), *Requirements Engineering: Social and Technical Issues*, London, Academic Press, 1994, pp. 217-240; P. Luff, C. Heath, *Mobility in Collaboration*, in *CSCW 1998: Computer Supported Cooperative Work*, atti del convegno (Seattle - WA, 14-18 novembre 1998), New York, ACM, 1998, pp. 305-314; J. Bowers, J. Pycock, J. O'Brien, *Talk and Embodiment in Collaborative Virtual Environments*, in *CHI 1996: Human Factors in Computing Systems Conference*, atti del convegno (Vancouver, 14-18 aprile 1996) New York, ACM, 1996; M. Rouncefield, H.A. Hughes, T. Rodden, S. Viller, *Working with "constant interruption": CSCW and the Small Office,* in *CSCW 1994: Computer Supported Cooperative Work*, atti del convegno (Chapel Hill - NC, 22-26 ottobre 1994), New York, ACM, 1994, pp. 275-286.

[7] J. O'Brien, *Management Information Systems: Managing Information Technology*, Boston, Irwin-McGraw Hill, 1999; P. Dourish, *Where the Action is*, Cambridge (MA), MIT Press, 2004.

[8] C.D. Kidd, R. Orr, G.D. Abowd, C.G. Atkeson, I.A. Essa, B. MacIntyre, E. Mynatt, T.E. Starner, W. Newstetter, *The Aware Home: A Living Laboratory for Ubiquitous Computing Research*, in *CoBuild 1999: 2nd International Workshop on Cooperative Buildings*, atti del convegno (Pittsburgh, 1-2 ottobre 1999), New York, ACM, 1999.

[9] G. Abowd, D. Mynatt, *Charting Past, Present, and Future Research in Ubiquitous Computing,* «ACM Transactions on Computer-Human Interaction (TOCHI)», 7, 1, 2000, pp. 29-58.

[10] A. Venkatesh, *Computers and other interactive technologies for home*, «Communications of the ACM», 39, 12, 1996, pp. 47-54.

e la tecnologia, mentre gli approcci convenzionali avevano studiato le caratteristiche esclusivamente delle famiglie, e non il loro rapporto con la tecnologia. Venkatesh tenta quindi di distinguere fra tre interfacce temporali e collegate tra il consumatore e la tecnologia nel sistema micro-sociale della famiglia. Si descrive che mentre molte ricerche hanno indagato l'importanza di adottare una nuova tecnologia per la casa, ma è solo un primo quadro, e incompleto, della totalità dell'interfaccia tra consumatore e tecnologia. Per avere il quadro generale di questa interfaccia bisogna considerare tre fasi fondamentali: l'adozione, l'uso e l'impatto.

Per quanto riguarda l'adozione di una nuova tecnologia per la casa, è importante considerare che le famiglie hanno delle ecologie interne e dei sistemi di valori, i quali entrano in gioco nell'adozione e nell'utilizzo di nuove tecnologie[11].

Venkatesh afferma che il fallimento dell'*Home Computing* è la conseguenza della mancanza di compatibilità con i tipi di attività e le pratiche che si svolgono all'interno dell'ambiente domestico. Il modello di Venkatesh rappresenta tre spazi concettualmente distinti: lo spazio sociale della famiglia, lo spazio di attività delle famiglie e lo spazio della tecnologia domestica. Nel quadro più recente[12] egli individua due "spazi chiave" differenti tra loro e collegati all'interno della casa: lo spazio sociale, che viene sostituito dalla struttura sociale della casa, e lo spazio tecnologico. Questi due spazi interagiscono in un complesso dinamico e imprevedibile, ed è proprio nella natura di queste interazioni e dinamiche che le tecnologie domestiche possono trovare il loro carattere. L'interazione tra la tecnologia e lo spazio sociale crea nuovi comportamenti e nuovi modelli di consumo; questo amplia chiaramente lo studio dell'interazione da un focus su un solo manufatto ai ruoli più ampi che la tecnologia può giocare nel contesto interazionale della casa.

Venkatesh, inoltre, ha proposto/teorizzato le cinque dimensioni delle tecnologie per la casa, che variano dalla dimensione strumentale-espressiva, funzionale oppure votata verso il trattenimento, passiva *vs* attiva, mono-funzione *vs* multifunzione, fino alla dimensione dell'impatto sociale della tecnologia.

O'Brien ha dichiarato che l'aspetto più importante della vita di tutti i giorni che è emerso dagli studi etnografici, è la "routine quotidiana" delle cose che devono "essere come dovrebbero essere". E ha scoperto/dimostrato che le attività di routine di tutti i giorni e l'insieme di diritti e doveri in casa sono strettamente intrecciati con la tecnologia. Il presupposto è che la tecnologia non solamente si inserisca all'interno della routine della vita, ma sia anche in grado di cambiare e modificarla. Il modello proposto da Venkatesh descrive anche uno degli effetti più importanti della tecnologia nella vita quotidiana: la generazione di pattern. L'approccio *pattern-based* è originariamente adottato dalle opere di Christopher Alexander[13]. Il lavoro di Crabtree[14] rappresenta un altro contributo alla comprensione delle circostanze sociali di utilizzo della tecnologia in ambiente domestico attraverso l'approccio *pattern-based.*

[11] J. O'Brien, *Management Information Systems: Managing Information Technology*, cit.

[12] A. Venkatesh, *Computers and other interactive technologies for home*, cit.

[13] C. Alexander, *A Pattern Language: Towns, Buildings, Construction*, Oxford, Oxford University Press, 1977.

[14] A. Crabtree, T. Rodden, *Domestic Routines and Design for the Home*, «Computer Supported Cooperative Work», 13, 2004, pp. 191-220.

Il *Pattern Language* ha avuto successo in ingegneria informatica e nella comunità della *Human Computer Interaction* e può diventare una risorsa molto importante per i team di progettazione.

Secondo il quadro di modello proposto da Crabtree i pattern di azioni e interazioni sono legati al particolare contesto, per esempio prendendo l'azione quotidiana del fare la doccia, questa è legata al contesto del bagno, così come il fare colazione è legato alla cucina. Come sottolinea Alexander, tutti i pattern sono ancorati nello spazio, quindi non possiamo immaginare o analizzare un pattern senza considerare il luogo dove questo accade.

Crabtree interpreta le due principali categorie di pattern, "primarie" e "secondarie", nella definizione di Alexander. Descrive che i pattern primari determinano il luogo (ad esempio facendo colazione, in cucina), mentre i pattern secondari possono essere una serie di componenti che costituiscono un pattern primario (ad esempio prendere il cibo dal frigorifero, ripulire il tavolo ecc.). Crabtree ritiene che la versione adattata del quadro dei pattern di Alexander sia molto utile nel processo di progettazione. Secondo la versione adattata del quadro di pattern di Alexander, i pattern delle relazioni rivelano quelli di utilizzo della tecnologia.

Molte tecnologie domestiche sono regolate dalle norme della casa e possono determinare chi usa quale dispositivo, quando, dove, se si paga, se il suo utilizzo dipenda dall'età degli utenti e lo scopo dell'uso della tecnologia stessa[15].

2.2 *User-centred design* vs *participatory design*

Il risultato di ogni processo di progettazione è un "artefatto". Ci sono due prospettive principali per quanto riguarda il manufatto: quella ingegneristica e quella architettonica. Dal punto di vista ingegneristico, l'esito del processo di progettazione è un *device* che fornisce agli utenti il facile accesso ad alcune funzioni: una sedia è un dispositivo per la seduta. Per le prospettive architettoniche, l'esito del processo di progettazione è una *thing* che modifica lo spazio in cui le persone vivono: oltre e al di là delle sue funzioni, la cosa progettata mira a migliorare l'esperienza degli utenti, è ricca di valori culturali ed estetici, apre nuovi modi di pensare e di comportarsi[16].

Vardouli afferma che nella ricerca progettuale "funzione" e "uso" sono stati sempre l'interesse centrale nella progettazione di un artefatto[17].

Ipotizzando che i progettisti vogliano evocare pensieri particolari, sentimenti, esperienze o azioni per gli utenti, il design diventa in questo caso un processo comunicativo, tra l'intento del progettista e l'uso da parte dell'utente.

Il design, in quanto processo di comunicazione tra un designer e un utente, mediato da un artefatto fisico, è un'idea che ha preso valore in architettura, nei modelli computazionali della linguistica e nella divulgazione della semiotica. Tuttavia l'applicazione della comunicazione nella progettazione si basa sulla teoria matematica di comunicazione di Shannon (1948). Il modello di Shannon consisteva originaria-

[15] A. Venkatesh, *Computers and other interactive technologies for home*, cit.

[16] T. Binder, *Design Things*, Cambridge (MA), MIT Press, 2011.

[17] T. Vardouli, *Making use: Attitudes to human-artifact engagements*, «Design Studies», 41, 2015, pp. 137-161.

mente in un mittente, un messaggio, un supporto ed un ricevitore/ricevente. Dal punto di vista del design il mittente è il designer, che intende trasmettere un particolare scopo o un valore (messaggio) per l'interpretazione (da parte di un utente-ricevitore/ricevente), attraverso un manufatto fisico (media/supporto)[18].

Il crescente interesse verso gli oggetti intelligenti è stato previsto a partire dai primi lavori sulle tecnologie domestiche e sull'*home computing*. La necessità di oggetti intelligenti meglio progettati e di metodologie di progettazione sono state discusse tra i vari ambiti di ricerca[19]. Una delle principali metodologie applicate al design dei prodotti intelligenti è il design incentrato sull'utente, ovvero lo *user-centred design*. Questo approccio mira principalmente a ridurre e semplificare le funzionalità e le interazioni del prodotto con l'utente. Ciò consentirebbe agli utenti di interagire in modo più naturale e intuitivo, e concentrarsi sui loro obiettivi e compiti invece che sulla tecnologia e l'interazione che questo richiede[20].

L'altro approccio è la progettazione partecipata ovvero il *Participatory design,* che è stato applicato anche nella progettazione di oggetti intelligenti[21]. La metodologia partecipativa dal 1970 ad oggi continua a rappresentare una pre-condizione per la progettazione di applicazioni software, anche se il pensiero di progettazione partecipata originale potrebbe essere modificato se ci si applica sulla *Ubiquitous Computing*.

L'impegno più esplorativo e informale con i partecipanti è necessario e, piuttosto che pianificare ogni dettaglio del progetto, la progettazione partecipativa ha bisogno di muoversi tra le iterazioni, le esplorazioni progettuali e gli esperimenti per fornire una comprensione necessaria delle situazioni e dei contesti complessi di applicazione della tecnologia avanzata di oggi[22].

3. *Metodologia*

3.1 *Condurre le interviste semi-strutturate*

Con l'obiettivo di validare e verificare quello che è definito in letteratura come una serie di fattori importanti da considerare durante il processo della progettazione per l'ambiente domestico, è stata condotta una serie d'interviste con quattro domande aperte. In totale, le otto interviste sono state condotte su tre diversi grup-

[18] T. Vardouli, *Making use: Attitudes to human-artifact engagements*, cit.

[19] R.D. Buurman, *User-centered design of smart products*, «Ergonomics», 40, 10, 1997, pp. 1159-1169; D.A. Norman, *The psychology of everyday things*, New York, Basic Books, 1988; Id., *The Design of Future Things*, New York, Basic Books, 2007; Id., *Living With Complexity,* Cambridge (MA), MIT Press, 2010.

[20] A.H. Marinissen, *Information on product use in the design process*, in *Ergonomics in a Changing World*, atti del 29th Annual Conference of the Ergonomics Society of Australia (Perth - Australia, 1-3 dicembre 1993), a cura di C.M. Pollock, L.M. Straker, Canberra, Downer - ACT Ergonomics Society of Australia,1993, pp. 78-85.

[21] M. Brereton, J. Buur, *New challenges for design participation in the era of ubiquitous computing,* «CoDesign», 4, 2, 2008, pp. 101-113.

[22] M. Brereton, J. Buur, *New challenges for design participation in the era of ubiquitous computing*, cit.; A. Brown, T. Green, *Issues and Trends in Instructional Technology: Lean Times, Shifts in Online Learning, and Increased Attention to Mobile Devices*, «Educational Media and Technology Yearbook», 36, 2011, pp. 67-80.

pi di professionisti, composti da ingegneri informatici, designer e psicologi di *User Experience* design.

Le domande erano così strutturate: la prima domanda richiedeva la definizione e la descrizione dell'approccio alla progettazione in generale; in seguito, sulla base della risposta, i concetti emersi venivano indagati più in dettaglio.

La seconda domanda aveva come obiettivo di indagare la fase valutativa della progettazione, chiedendo ai partecipanti come valutano un outcome di un processo di progettazione, quali fattori vengono considerati e perché.

La seconda sezione si è concentrata ulteriormente sul processo della progettazione per l'ambiente domestico, indagando i fattori più importanti da considerare prima e dopo la progettazione. E l'ultima domanda aveva come obiettivo quello di capire quali dei fattori strettamente legati all'ambiente della casa vengano considerati per la progettazione di artefatti connessi per la casa.

La durata media delle interviste è stata di circa 15 minuti e queste sono state condotte al Politecnico di Torino, sede di Mirafiori, e al Joint Open Lab, laboratorio dell'innovazione di TIM a Torino, nel mese di febbraio del 2016.

L'età media dei partecipanti alle interviste è trentacinque anni.

3.2 *Analisi del contenuto*

È stata effettuata una serie di trascrizioni delle interviste, mettendo in ordine i contenuti. In seguito è stata condotta un'analisi del contenuto, clusterizzando le parole che sono state ripetute, secondo diverse caratteristiche dell'artefatto progettato. Le caratteristiche sono state scelte sulla base dell'osservazione delle risposte.

3.2.1 *Processo della progettazione*

Le definizioni e le parole chiave fornite dai partecipanti sono state clusterizzate e rappresentate su due assi. L'asse verticale riguarda gli aspetti collaborativi e l'interdisciplinarità del processo a seconda della percezione che l'intervistato ha di un lavoro di progettazione che varia da un processo partecipativo a uno individuale. L'asse orizzontale riguarda gli aspetti legati all'approccio, che variano dagli aspetti razionali agli aspetti emotivi.

La categoria A (designer) di partecipanti ha dimostrato che gli aspetti razionali-collaborativi sono i più importanti in un processo di progettazione, così come il fatto di poter avere molteplici feed-back durante e dopo la progettazione. Il feed-back in particolare è stato definito utile non solo per migliorare il funzionamento dell'oggetto, ma anche gli aspetti emotivi che l'oggetto ha, se questo sia piaciuto o meno e quale relazione si possa creare tra l'oggetto e l'utente. L'altro aspetto della progettazione messo spesso a fuoco dai designer è stato quello di esplorare e trovare sia il problema, sia la soluzione.

La categoria B (ingegneri) ha dimostrato maggiormente che la progettazione è un processo che comprende sia gli aspetti individuali, sia quelli collaborativi; mentre gli aspetti razionali sono molto salienti, quelli emozionali sono stati poco espressi. In particolare, la parola "iterare" nel processo di progettazione è stata ripetuta più volte rispetto che nelle altre categorie.

Per quanto riguarda la categoria C (psicologi, UX), la progettazione è stata definita maggiormente come un processo collaborativo-emotivo. In particolare la fase di ideazione, oppure il creare l'idea giusta – costruirla in modo chiaro – sono stati enfatizzati maggiormente rispetto agli altri gruppi.

3.2.2 *Progettazione per l'ambiente domestico*

Anche in questo caso, le definizioni e le parole chiave fornite dai partecipanti sono state clusterizzate e organizzate su due assi. L'asse verticale riguarda le caratteristiche dell'oggetto o del servizio per l'ambiente domestico, che varia dagli aspetti fisici a quelli emotivi. L'asse orizzontale riguarda invece gli aspetti fisici legati all'ambiente domestico (per esempio la tipologia di abitazione) e quelli più contestuali, che riguardano più la natura dell'ambiente (per esempio un ambiente intimo).

Da questa seconda analisi è emerso che la categoria A risulta più sensibile e attenta agli aspetti contestuali e funzionali dell'ambiente domestico, mentre gli aspetti fisici ed emozionali sono ritenuti meno importanti oppure secondari. In particolare sono state enfatizzate diverse volte le abitudini delle persone all'interno della casa come un fattore molto importante.

Anche la categoria B ha dimostrato che è più attenta agli aspetti contestuali e funzionali dell'ambiente domestico, ma ha anche enfatizzato la struttura architettonica della casa come un fattore importante per la progettazione per la stessa.

La categoria C ha dimostrato che gli aspetti emotivi-contestuali dell'ambiente domestico sono quelli più importanti da considerare nella progettazione per questo ambiente. In particolare il concetto di privacy è stato espresso come il fattore più importante della casa, dal momento che questo ambiente è un ambiente intimo ed è il luogo in cui si trovano le cose che ci appartengono.

La progettazione per l'ambiente domestico è un processo interdisciplinare che necessita di considerazioni diverse per quanto riguarda gli aspetti funzionali-emotivi, oppure gli aspetti fisici-contestuali, ma anche l'intervento di professionisti diversi. Questo studio lo conferma ulteriormente.

4. *I limiti dello studio*

Questo studio ha evidenziato alcuni limiti rispetto al campione selezionato. Il campione ha infatti presentato una dimensione ridotta per quanto riguarda le persone che si occupano della progettazione negli ambienti di ricerca e innovazione.

5. *Implicazioni*

Il risultato di questo lavoro potrebbe aiutare le ricerche teoriche future nel campo delle metodologie della progettazione. Questo studio può essere soprattutto di supporto alle metodologie che considerano l'interdisciplinarietà come un fattore fondamentale di ogni processo di progettazione ed enfatizzano il fattore sociale e collaborativo di tali processi.

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Bibliografia

G. Abowd, D. Mynatt, *Charting Past, Present, and Future Research in Ubiquitous Computing*, «ACM Transactions on Computer-Human Interaction (TOCHI)», 7, 1, 2000, pp. 29-58.

C. Alexander, *A Pattern Language: Towns, Buildings, Construction*, Oxford, Oxford University Press, 1977.

K. Ashton, *That "Internet of Things" Thing, in the real World Things Matter More than Ideas*, «RFID Journal», 2009, www.rfidjournal.com/article/print/4986.

R. Bentley, J.A. Hughes, D. Randall, T. Rodden, P. Sawyer, D. Shapiro, I. Sommerville, *Ethnographically-Informed Systems Design for Air Traffic Control,* in *CSCW 1992: Computer Supported Cooperative Work*, atti del convegno (Toronto, 1-4 novembre 1992), New York, ACM,1992.

T. Binder, *Design Things*, Cambridge (MA), MIT Press, 2011.

J. Bowers, J. Pycock, J. O'Brien, *Talk and Embodiment in Collaborative Virtual Environments*, in *CHI 1996: Human Factors in Computing Systems Conference*, atti del convegno (Vancouver, 14-18 aprile 1996), New York, ACM, 1996.

M. Brereton, J. Buur, *New challenges for design participation in the era of ubiquitous computing,* «CoDesign», 4, 2, 2008, pp. 101-113.

A. Brown, T. Green, *Issues and Trends in Instructional Technology: Lean Times, Shifts in Online Learning, and Increased Attention to Mobile Devices*, «Educational Media and Technology Yearbook», 36, 2011, pp. 67-80.

M. Brereton, J. Buur, *New challenges for design participation in the era of ubiquitous computing,* «CoDesign», 4, 2, 2008, pp. 101-113.

G. Button, W. Sharrock, *Occasioned practices in the work of software engineers*, in M. Jorotka, J.A. Goguen (a cura di), *Requirements Engineering: Social and Technical Issues*, London, Academic Press, 1994, pp. 217-240.

R.D. Buurman, *User-centered design of smart products*, «Ergonomics», 40, 10, 1997, pp. 1159-1169.

Connected homes. An Ericsson Consumer Insight Summary Report, Stockholm, Ericsson ConsumerLab, 2015; disponibile presso: https://www.ericsson.com/res/docs/2015/consumerlab/ericsson-consumerlab-connected-homes.pdf.

A. Crabtree, T. Rodden, *Domestic Routines and Design for the Home,* «Computer Supported Cooperative Work», 13, 2004, pp. 191-220.

P. Dourish, *What we talk about, when we talk about context*, «Personal and Ubiquitous Computing», 8, 1, 2004, pp. 19-30.

— *Where the Action is*, Cambridge (MA), MIT Press, 2004.

J. Hughes, J. O'Brien, T. Rodden, *Understanding Technology in Domestic Environments: Lessons for Cooperative Buildings*, in *Integrating Information, Organization and Architecture*, *CoBuild 1998*, atti del convegno (Darmstadt, 25-26 febbraio 1998), a cura di N. Streiz, S. Konomi, H.J. Burkhardt, Berlin, Springer, 1998.

C.D. Kidd, R. Orr, G.D. Abowd, C.G. Atkeson, I.A. Essa, B. MacIntyre, E. Mynatt, T.E. Starner, W. Newstetter, *The Aware Home: A Living Laboratory for Ubiquitous Computing Research*, in *CoBuild 1999: 2nd International Workshop on Cooperative Buildings*, atti del convegno (Pittsburgh, 1-2 ottobre 1999), New York, ACM, 1999.

P. Luff, C. Heath, *Mobility in collaboration*, in *CSCW 1998: Computer Supported Cooperative Work*, atti del convegno (Seattle - WA, 14-18 novembre 1998), New York, ACM, 1998, pp. 305-314.

A.H. Marinissen, *Information on product use in the design process*, in *Ergonomics in a Changing World*, atti del 29th Annual Conference of the Ergonomics Society of Australia (Perth - Australia, 1-3 dicembre 1993), a cura di C.M. Pollock, L.M. Straker, Canberra, Downer - ACT Ergonomics Society of Australia,1993, pp. 78-85.

D.A. Norman, *The Psychology of Everyday Things*, New York, Basic Books, 1988.

— *The Design of Future Things*, New York, Basic Books, 2007.

— *Living With Complexity*, Cambridge (MA), MIT Press, 2010.

J. O'Brien, *Management Information Systems: Managing Information Technology*, Boston, Irwin - McGraw Hill, 1999.

M. Rouncefield, H.A. Hughes, T. Rodden, S. Viller, *Working with "constant interruption": CSCW and the small office,* in *CSCW 1994: Computer Supported Cooperative Work*, atti del convegno (Chapel Hill - NC, 22-26 ottobre 1994), New York, ACM, 1994, pp. 275-286.

The Era of Living Services, London, Fjordnet Ltd, 2014, https://livingservices.fjordnet.com/media-files/2015/09/living-services.pdf.

T. Vardouli, *Making use: Attitudes to human-artifact engagements*, «Design Studies», 41, 2015, pp. 137-161.

A. Venkatesh, *A Conceptualization of the household/technology interaction*, «Advances in Consumer Research», 12, 1985, pp. 189-194.

— *Computers and other interactive technologies for home*, «Communications of the ACM», 39, 12, 1996, pp. 47-54.

M. Weiser, R. Gold, J.S. Brown, *The origins of ubiquitous computing research at PARC in the late 1980s*, «IBM Systems Journal», 38, 4, 1999, pp. 693-696.

[Post-print Version]: forthcoming in Design Issues 34 (2). MIT press.

Thinking with Interactive Artifacts:

Reflection as a Concept in Design Outcomes.

Maliheh Ghajargar, Mikael Wiberg

Abstract

Reflection is a recurring notion in the HCI/interaction design literature. Throughout the years "reflection" has been highlighted as a key dimension of design thinking and as an important ingredient of design processes. In this paper, we take stock in our community's interest in reflection and we suggest that while it has been acknowledged as a cornerstone for design processes, it has been less explored as a basis for design outcomes. In an attempt to approach this research problem, we conducted an extensive literature study. This study included a keyword analysis first in Scopus database and then in ACM library. In total, we filtered among 1,771 scientific papers.

Given this extensive literature study, it seems that 1) the interest in this area is growing and we present tables that illustrate this growing interest over time, 2) reflection and behavioral change are two interrelated notions, and 3) these notions are well-explored in our field. Further on, we suggest that as interaction design is increasingly exploring the design of "tangible", "smart", "connected" and even "intelligent" artifacts, we should think about how reflection, and our ability to "think with artifacts" can be extended to include the design of interactive artifacts. In this paper, we suggest how that might be done and we point at a design space for designing such interactive artifacts to think with.

Keywords: Reflection, Interactive Artifacts, Behavior Change, Materiality and Tangibility

Introduction

In Donald Schön's book "The Reflective Practitioner" the notion of *reflection* is highlighted as a key for meaningful design processes. [1] Further on, in other work he highlights how reflection happens during the design process through "conversations with the materials at hand". [2] Accordingly, his work describe how reflective processes are entangled with behaviors and how the hands are part of exploring the materials, and so reflection is at the same time entangled with the materials and artifacts at hand. In short, reflection is an activity that is inseparable from behaviors and artifacts and other things. [3]

The importance of reflection has not only been highlighted by Donald Schön, but has been a recurring topic for HCI research. For instance, Stolterman and Löwgren confirm in their book "Thoughtful interaction design" how it is the design thinking, i.e. reflections, that is key for designing good and meaningful interactive systems. [4]

In this paper, we take stock in our community's interest in how *reflection* is fundamentally entangled with *behaviors* and *artifacts/things.* We do this through an extensive literature study as a point of departure for exploring how reflection might not only be an essential aspect of design process, but how it might also serve as a design concept. In detail, we do that in this paper by presenting a literature study on how the notions of reflection and behavior, including behavioral change, has so forth been explored in HCI/interaction design research. One assumption we have is that we do not only have "conversations with materials" but that these conversations also affect our thinking and accordingly might lead to changes in our behaviors.

As we will demonstrate through the presentation of this study such changes in behavior has so forth been explored in relation to the design process and the design outcome.[5] However, in this paper we describe how we are also interested in exploring if this idea of how *"reflection-behaviors-artifacts"* are entangled might also be thought of as a basis for design of "smart" or "wise" things. Accordingly, we also discuss the contemporary development in the area of "smart artifacts", "tangible interaction", the "Internet of Things", and so on. As formulated by Sherry Turkle, we usually consider objects as useful or aesthetic, but less as our companions or provocations of thoughts.[6] Accordingly, if we can more thoughtfully design such things, then that might be key in terms of tackling problems that might demand behavioral changes, such as in the area of sustainability and health.

The rest of this paper is structured as follows. First, we describe briefly the methodology behind our literature studies. We then present a background on the use of reflection in HCI and the way it can contribute to behavior change. Further on we describe and discuss what we mean when we talk about interactive artifacts. Having done that the following section illustrates the difference between artifacts that support behaviors and activities and those that make people think on their behaviors. Then, we move to a discussion on the role that materials and the materiality of interaction might play in order to influence reflective thinking. We conclude the paper by summarizing our results and we wrap up the paper with some questions for future research.

Methodology

In order to understand how the *"reflection-behavior-artefact"* relation has been expressed in the literature, we performed a keyword analysis first in Scopus database and then within the Association for Computing Machinery (ACM) library.

An initial research in Scopus database, brought up a total number of 1,771 scientific papers about "Behavior Change Design" mostly from medicine, computer science and social science studies. Then we filtered and categorized the results following keywords: 1) "Reflection": 85 papers since 1966, mostly from medicine, computer science and nursing studies; 2) "Smart Object": 15 papers, from computer science studies, since 2006; 3) "Tangible User Interface": 8 papers from computer science studies, since 2005. Then we made a similar research in the ACM library, which brought up a total number of 1,884 scientific papers which contain "Behavior Change" among their author keywords. Then we filtered them through following keywords: 1) "Reflection": 762 papers since 1971; 2) "Smart Object": 71 papers since 1971. These keywords have been selected to circle the relation between smart artifacts, behavior change and reflection. Although we filtered the results also by "Tangible User Interface", we have then excluded this from our results. Because most papers were focused on the behavior of the tangible user interface and not about inquiries on how such interfaces can influence human behavior.

We made also another refined and more focused keyword based research study in ACM library to filter and categorize the literature on designing systems that promote behavior change in HCI. In particular, we sought to find out the number of times that Behavior Change (BC), Sustainable Behavior Change (SBC), Health Behavior Change (HBC) and Reflection Behavior Change (RBC) have been appearing among the keywords of the ACM library publications over the last ten years (Figure 1). Specifically, BC is the extended notion, that covers the whole range of research areas of behavior change design, while the others are related to specific areas of design for consumer behaviors change, namely: SBC in sustainable energy and water consumption; HBC in health, food, and sport; and RBC in quantified self and self-reflection on personal data.

Among the different areas related to behavior change, HBC resulted one of the growing ones, and more explored than others. The SBC, although currently shows one of the areas with the lowest number of publications, it is slightly increasing.

Finally, the RBC line shows the one of the highest percent of increment among other areas. Although the line smoothly fluctuates since 2007, it keeps its growth with the highest value in 2014, resulting in a growth of 22% in comparison with the same value for the previous year.

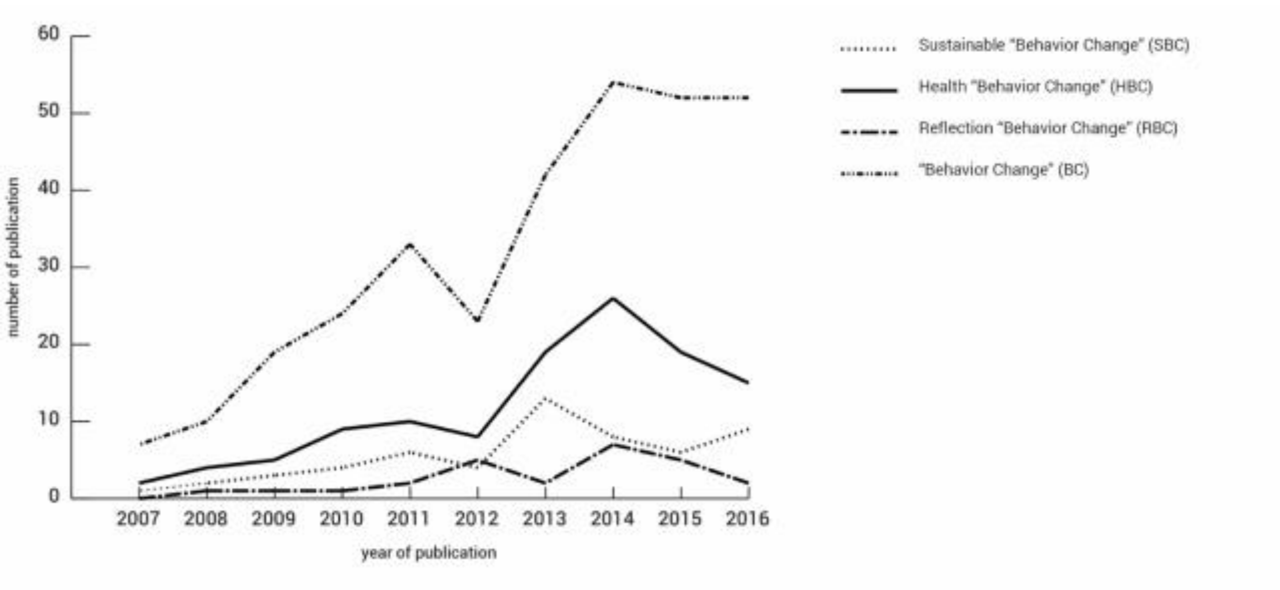

Figure 1 - Number of papers on Behavior Change in the last ten years of ACM publication.

With the purpose of capturing the relevance and the relation between Behavior Change (BC) and reflection, we also conduct a keyword analysis in the last ten years of ACM publications for the keywords Reflection Behavior change (RBC), Reflection Health Behavior Change (RHBC) and Reflection Sustainable Behavior Change (RSBC). Figure 2, shows the growth, yet fluctuating trends of all these keywords. In particular, the number of papers including the RHBC and RSBC keywords is increasing although fluctuating, over the years.

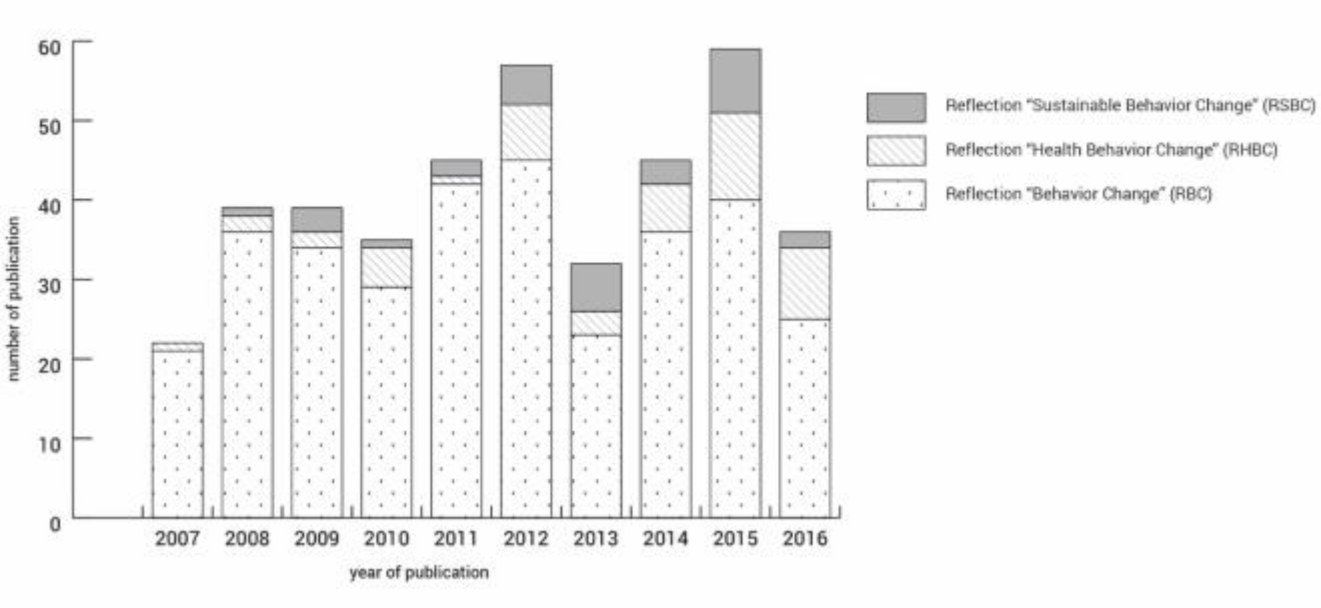

Figure 2. Number of papers on Reflection and Behavior Change in the last ten years of ACM publications.

Lastly, Figure 3 shows the relevance of available literature that explicitly deals with Smart Objects (SO) and with the relationship between SOs, BC and reflection. It shows that the number of papers including the keyword SO has been increasing over the years, but only a few of those papers are related to the notions of reflection (RSO) and 13% of the total publications on SOs has also the BC among author keywords (BCSO). This might explain that researches on SOs is mostly focused on designing SOs technical features rather than exploring the way SOs can affect the users and their behaviors.

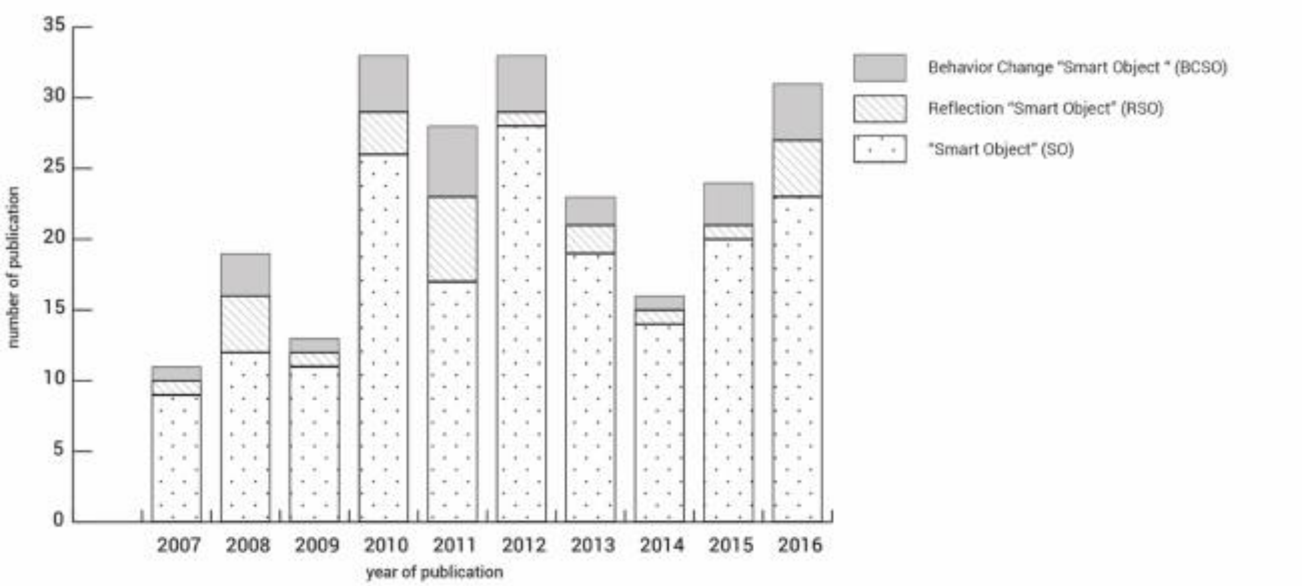

Figure 3. Number of papers on Smart Object and Behavior Change in the last ten years of ACM publication.

In summary, the BC keyword is available in a number of papers. However, just 5% of those is associated with the application of reflection and just 4% of the total publications deal with the possible relation between reflection and SOs. Although this is a very new topic with a relatively small number of papers, represents one of the growing areas of interest within HCI community researchers.

Reflection in HCI

The notion of reflection is of great interest to the HCI (Human-Computer Interaction) community in several research areas, specially as a way to do research in informatics and also as a way of using technology to support learning and playing.[7] It has been also for instance the subject of researches in the area of behavior change design in health and sustainability, critical design and in interaction design process in general. Researches in this area range from theoretical to the practical and tangible contributions. The theoretical contributions are mostly about reflective process of designing interactive artifacts employing new ways and tools for supporting that process. Few works are about using reflection as an alternative way to the persuasion-based design systems. In practical and tangible contributions, for instance eco-feedback technologies and ambient lights, aim to reduce energy or water consumptions by providing tangible, mostly lighting feedbacks on mobile devices or through a tangible artifact in domestic environment.[8]

In these domains, 'reflection' refers to the action of reflecting on information provided, and being informed about the consequences of an action or behavior and to create puzzling and surprising effects.[9] The activity of reflecting on the actions previously done, is called *Reflection-on-action*, which differs from *Reflection-in-action*, that is related to reflecting while doing an activity.[10] Thus, the first is about recalling memories and experiences and then reflecting on, while the second concerns about reflecting, while the action is being done. For this purpose, data, which are visualized to bring into mind and be used for further reflection, reduces the need for storing and memorizing personal experience, but encourages recalling them when required. For design of such purposes, relevant conditions for reflection should be considered, which are time, motivation, skills, guidance and encouragement.[11] This means that reflection as a temporal process needs time, other external factors that guide and encourage people towards reflection (i.e. a mentor). Moreover, social interactions also seem having a relevant role because they call for the possibility to talk with other people about experience and this help to recall memories. Therefore, interactive systems for behavior change, increasingly, focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action.[12]

The representation of social traces, social support and collective use, that are essential parts of Behavior Support Systems, go beyond the mere representation of sensor data collections and seek to provide structured information frameworks and patterns, in order to enhance reflection.[13]

In this context, the relation between data visualization and reflection has already been investigated in the HCI literature over three different perspectives: 1) the representation of data that stimulate reflection (e.g. through the form and the degree of ambiguity of data visualization: lists support ordering of information, trees show hierarchies, and tables show relations between data points);[14] 2) the way people perceive data representation, for instance accountability and playfulness vs. intrusiveness and guilt;[15] and 3) the social and personal influences of data visualization, such as patterns of social learning and facilitation, competition, cooperation, and recognition.[16]

Sas and Dix consider reflection as the final aim of the design process, so they propose to design technologies to support people's reflection on personal experiences. [17] Fleck and Fitzpatrick considers an opportunity to not just using reflection as the main purpose for design, rather as a medium to reach a purpose. Therefor technology is not just used to cause reflection, but rather to help reaching a higher level of reflection that is required for behavior change as a purpose and intent of the system.[18]

Does Reflection "mediate" behavior change?

Reflection as a driver for behavior change has been largely investigated in learning, professional and organizational contexts.[19] Generally, it affects the learning process by enabling the review and merging of a series of previous experiences and events to help a better understanding or to gain some sort of insight.

In particular, Schön in 1983, stated that reflection is a type of 'thinking about' that enables a kind of problem solving involving the construction of an understanding and reframing. Therefore, reflection is a form of thinking that reframe the situation and enables different kinds of decision making, otherwise unachievables. This emphasizes the role of critical thinking as an essential tool to allow people make conscious value choices in their attitudes and practices, which go beyond simply opening new options for designers (Figure 4). It concerns bringing unconscious aspects of experience to conscious awareness, thereby making them available for conscious choice.[20]

Reflection has been also considered as a *tool* to provoke a new way of thinking, so that some interactive experiences are said to provoke reflection or invite to reflect.[21]

All these contributions agree that the reflective practice requires an external entity, usually another person as a *mentor*, who is able to propose appropriate stimuli and questions at the right time.

Sengers et al. in particular reflects on the role of technology in this sense by defining 'Reflective Design' as a practice, which combines analysis of the ways in which technologies reflect and perpetuate unconscious cultural assumptions, with design, building, and evaluation of new computing devices that reflect alternative possibilities. [22]

Hence, two distinctive but relative topics emerge. One is about the design activity and concerns the designer's reflective activity as a professional practitioner.[23] The other one is related to the artifact and technology able to evoke reflective kind of thinking in people. In this latter, reflection becomes the primary intent and as a concept for design of such artifacts, and is the main focus of this paper.

According to literature, technological artifacts can evoke reflection in users and support them to make conscious decisions, but seems that there is a lack of studies regarding how interactive artifacts, mediate reflection. Reflection that mediates between user and user's behavior is illustrated in figure 4.

To moving forward, we need to illustrate the role of the artifacts in relation to this model, accordingly the next chapter is dedicated to this topic, and we seek to provide an overview on the use of interactive and smart artifacts to stimulate behavior and evoke reflection.

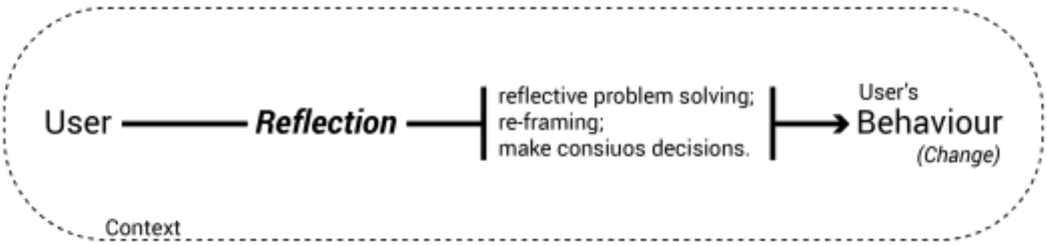

Figure 4: Reflection as a medium between user and user's behavior.

When artifacts become interactive

What is an artifact? This topic has been debated for many years, and so we start with some historical notes. Aristotle divided existing things into those that "exist by nature" and those existing "from other causes." The latter concerns designed things and artifacts, which has been considered as the outcome of any design process.[24]

According to Stolterman and Nelson, designed things do not exist by nature, rather they become created by human according to needs, intentions or irritation.[25] This is the type of thing that we focus on in this paper: artifacts. Therefore, first of all we bring some definitions about what artifacts are and what kind of artifacts we are focusing on in this paper.

Definitions of artifacts stretches across different orientations in literature. For instance, many seminal works done by authors such as Simon and Crilly define artifacts, according to what is their goal and functions.[26] On the other hand, Gero's FBS ontology describes artifacts not only based on their goals and *functions* but also according to their *behaviors* and *structures*, which are necessary for achieving goals.[27] Thus what artifacts are for, depends on the way they behave and the *structure* that enable those behaviors. However, those *behaviors* and *structures* (i.e shape, color, composition, etc.) influence the use, the user's activity and behavior, through interaction and use, the latter in most cases is closely related to the artifacts' affordance.[28]

Hence, artifacts have been considered as passive tools for achieving predefined goals through use and function. It is also considered that they can influence human behaviors whether support or change behaviors. They are also able to evoke thoughts in different ways, for instance through appearances, materials, behaviors, affordances, functions and also through memories and experiences that they hold.[29]

But what happen if they become interactive, smart and connected to the Internet?[30] if we use artifacts that are not anymore considered as passive tools, how can they evoke thoughts? how can they change user's behavior instead of support them through evoking thoughts and reflection?

When artefacts become interactive and smart

Research on smart artifacts and the Internet of Things has been going on for nearly two decades since Mark Weiser's vision of Ubiquitous Computing.[31] Emerging technologies, have been enabled building a range of computationally enhanced and Internet-connected devices commonly called "smart artifacts", "semantic devices", "connected artifacts" and etc. They can sense, log and interpret what's occurring in their context and can interact, intercommunicate and exchange information with other artifacts and also with users.[32]

Smart objects have been defined also by various research areas of business, ambient intelligent and web semantics.[33] Kortuem, et al. for instance introduce a hierarchy of architectures for those artifacts, particularly describe activity-aware, policy-aware and process-aware smart artifacts.[34]

However, the three main relevant functions and characteristics of smart artifacts presented in the literature are as follows:

> **Reactivity and Context-awareness:** the ability of smart artifact to understand events and human activities occurring in a given physical world and physical representation.[35] In design fiction literature, it is defined as a space-time artifact, aware of their surroundings, memorizing real-world events or as the artifacts able to perform and act without human guidance.[36] In Artificial Intelligence (AI) arena, those artifacts are called *situated agents*; *reactive* or *behavioral agents*, which include also the adaptation and reaction to the situation.[37] Situatedness, nevertheless, is defined from the design community as a fundamental feature of such agents.[38]
>
> **Proactivity:** smart artifacts should act autonomously, anticipate and control the situation in order to be considered a proactive artifact.[39] Therefore social ability, participation and responsiveness have been considered some other properties for those artifacts.[40]

Preemptive: smart artifacts are supportive and they predict errors and faults, thus seek to remove unpleasant surprises from the user's life.[41]
Interactivity: smart artifacts converse and interact with the user in terms of inputs, outputs and feedbacks in a simple and intuitive way. Mühlhäuser defines them as artifacts, software or services that have improved simplicity in terms of interaction with the user and facilitated openness to connect and to communicate with other devices.[42] Janlert and Stolterman has been recently investigated the phenomenology of interactivity. They defined interactivity as an activity and a process, which can be measured. Further, these authors have suggested *Interactability,* describing the potentiality of artifacts and systems to be engaged in interaction.[43]

Despite the large literature and discussion around these four mentioned features, the ability of smart artifacts to stimulate human reflective behavior and to evoke thoughts in user is still little explored. However, self-reflection on personal informatics has been primarily evoked through data visualization and personal images/videos on mobile apps, websites, displays on wearable devices, and environmental installations.[44]

When interactive artefacts "mediate" *behaviors*

In general, four basic factors play important roles in human–artifact interaction: the artifact, the user, the user's goal, and the context where the interaction takes place.[45] These factors can be extended also to the network with other products and people who are involved in or affected by the product use, up to any product-service combination.[46]

The idea of designing for user's behavior has been developed in the studies on design by Donald Norman.[47] His early works introduced for the first time human cognitive and psychological factors into design research, such as the concepts of affordance, constraint and feedback, which later become the basis of Interaction Design.[48] The notions of "usability" and "experience" become later the two key aspects in design, which requires a deep understanding of the way people interact with artifacts, with the purpose of making the designed artifact as easy and pleasant as possible for use and to support user's behavior.

Considering the design process of such artifacts, the common factor among these approaches although originating from different sources, is that the design practice is intended. There is always a designer's intent that expects to be realized in a certain user behavior during or after the interaction with the artifact. [49]

The idea of using the features of an artifact to mediate or to evocate to change, instead of support a user's behavior has been expressed in a number of different approaches, such as in Lockton's Design with Intent and Niedderer's Performative Artifacts(Figure 5). In design with intent, in most cases an artifact is designed in a way so to avoid some user's behavior.[50] Moreover, the Performative Artifacts (POs), invite users to behave in a particular way. In designing POs, designers design also user activities, which do not occur independently from the product.[51] In either examples, the artifact function is to "do not support" a user's habit or behavior, but to avoid them or to invite to some other kind of behaviors, through unfamiliar uses and functions. This unfamiliarity put users in a new condition and guide them through a process that make them think about it, by manipulating and sensing the artifact. Thus the artifact's characteristics such as textures, shapes, etc. play fundamental roles.

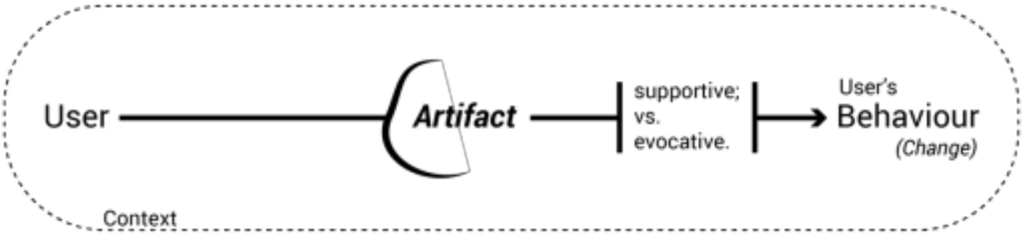

Figure 5: Artifacts as a medium between user and user's behavior.

Since the computational and artificial intelligent development has been growing, we are designing not only physical and traditional artifacts but also digital artifacts. Digital artifacts are known mostly as computers, websites, mobile applications and interactive displays and any other form of artifact which have embedded-in some form of computing technologies. The interests in designing for human behavior change in HCI has seen growing since we tackle problems in many areas related to health, environmental and social sustainability.[52]

Although digital artifacts have some physical parts, they may have lost many of physical qualities, such as the material qualities, texture and patterns.[53]

To restore the quality of physical interaction with materials, many researchers worked on the sensorial properties of the digital artifacts, such as attributed color and sound, in order to shape particular perception and experience, and affect human behaviors.[54] For example, colors can influence social dining behavior in dining rooms or changing the people's mood.[55] Products intentional sounds used to improve the user-artifact interaction with a mean of feedback, instead, are proved to influence user experience and their behavior through auditory possible semantic associations.[56]

In this sense, there are various opportunities in applying technologies to stimulate human senses which goes beyond just visual and tactical perception.[57] These opportunities have proved to be useful in the creation of novel interactions. For example, Gaver's auditory interfaces and Kramer's auditory displays are tow examples of exploration of the potential of auditory periphery interaction.[58] Bakker's works in particular, focus on physical interaction and auditory interaction in the periphery of our attention.[59]

When interactive artefacts "mediate" *reflection*

Currently, the literature neither presents any definition of artifacts that stimulate reflections nor identifies what features such artifacts should have. In this chapter we will just briefly introduce the available concepts and theories, which argue about physical and smart artifacts as mediums of reflection.

The concept of Slow Technology, for instance, concerns a category of physical artifacts that are not "used" at all, but instead support activities located within the environment.[60] Although the "slowness" of technology as a feature has been associated to the simplicity and modest appearance of the artifacts, similar to the Weiser's calmness of technology, it is based on concepts as appearance, presence, expression, and environmental interaction. These factors are proved to evoke reflection and might lead to influence user's behaviors if reflection reaches its higher levels.[61]

Furthermore, Dietrich and Laerhoven demonstrated the mediating character of wearable technologies for reflection.[62] They have merged the concepts and theories about mediated role of technology with Dourish's embodied interaction.[63] Embodied Interaction, is the type of interaction that occurs due to the realization and concretization of data and it may overlap with Tangible Interaction in various forms. Tangible Interaction combines the properties of both physical and digital entities through the use of physical artifacts to represent and control digital data.[64] Embodied Interaction views tangibility as a key mean of interaction with the physical world, but it takes a broader stance by envisioning meaningful interaction with technology inspired not only by physical but also social phenomena of everyday life. [65]

Using tangible artefacts as mediums of reflection has been also explored for several purposes. For instance, Lover Box is a tangible artifact that encourages couples to reflect on their relations, Data Souvenir is an augmented book with hardware and software that applies the environmental psychology for reflections in home environment.[66]

Despite growing interest and availability of these technologies, designing for reflection is still in its early stages. Even though tangible user interfaces are becoming diffused in smart artefacts, there is still a lack of studies regarding the exploration of the novel forms of tangible interaction that can promote reflection and in particular the role that materials play in that sense. In moving forward, we add to our model the notion of evocative as to speak about the ways, through which we can design artifacts to think with (Figure 6).

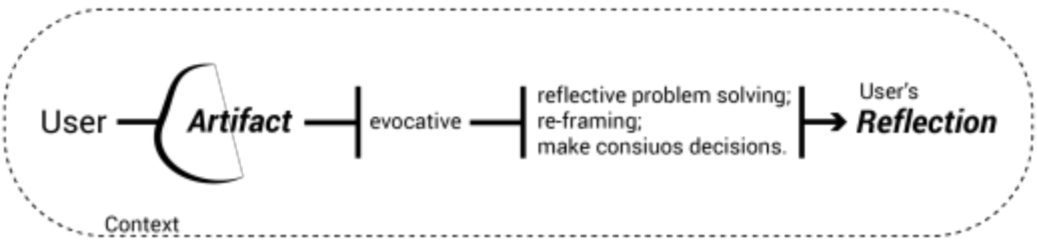

Figure 6: Artifacts as a medium between user and user's reflection.

Materials for reflection and materiality of reflective interaction

Designing for reflection is still in its early stages, but we see great potential for moving forward. Our motivation for doing so is grounded in several contemporary trends. The literature study we have presented in this paper illustrates the growing interest in our community in the role of reflective thinking in design processes, and also its implications in behavior change processes. It is also evident that interests are growing toward using computational artifacts as an outcome of the design process able to stimulate reflection in user. Further on, and as we are pushing the technological envelope further towards "tangible", "faceless", "smart" and "intelligent" artifacts, we should for sure not only think about how to design such "smart" artifacts, but how we might consider the outcome of design as an interactive artifact to think with.[67] In designing interactive artifacts, the interests are shifting from virtual and immaterial to formal and physical representation of information, this has opened up a new dialogue on material turn, which acknowledges that computing is changing forms, so the substances of the interaction is changing as well. This opens the perspectives towards the relevance of the materiality in interaction, so not only investigating on the physical substance and properties of the forms and materials, but also using that as a resource for cultural, aesthetic and thoughtful forms of interaction.[68]

Therefore, we believe in designing interactive artifacts to think with, the reflection as a kind of thinking, can be considered as a medium, and turn into the material of the human-artifact interaction.

This design challenge makes this paper go full circle. We opened up this paper with a discussion on Donald Schön's work on "conversations with materials" and we set that in relation to Sherry Turkle's idea that we can use certain things as artifacts to think with.[69] Further on, the literature study shows there is a growing interest in reflection in our community, and in the design of "smart artifacts", and we are increasingly discussing this through "the materiality of interaction". Thus the *realization of the interaction through computational re-activation of traditional and analogue materials* is turning into the purpose and challenge of many design researchers.[70]

In short, as interaction design is increasingly about: 1) the design of interactivity as a process and activity in the form of interactive and smart artifacts; 2) exploring the potential of "reflection" and "behavior change" through designing novel forms of interactions and 3) designing tangible and physical "smart" artifacts for the Internet of Things, then we see a big opportunity here for using reflection as a design concept. Hence designing "smart" and interactive artifacts, using the materiality of reflective interaction as a medium for behavior change.

Considering this opportunity, which is well theoretically grounded, we now seek to open up two approaches for designing concrete and formal interactive artifacts:

1) *Materials for reflection*, which is about designing tangible artifacts, using radical atoms and material turn to evoke thoughts and reflection in user with the purpose of behavior change. This approach focuses mostly on the material properties of artefacts such as shapes and textures and compositions (Figure 7);

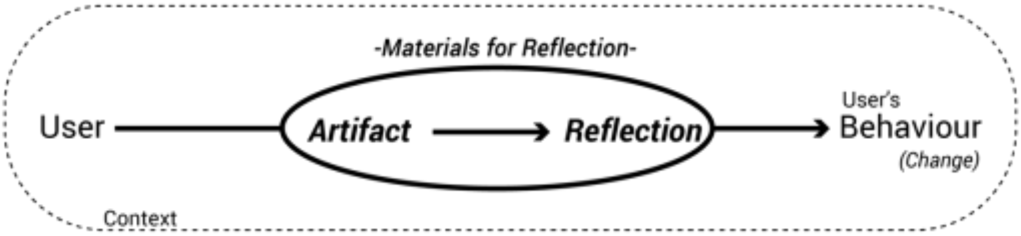

Figure 7: Materials for Reflection

2) *Materiality of Reflective Interaction*: which is about designing interactions, which are tangible, embodied and reflective. Those interactions are able to shape strong cultural and aesthetic forms of reflective interactions and to mediate between user and user's behavior (Figure 8).

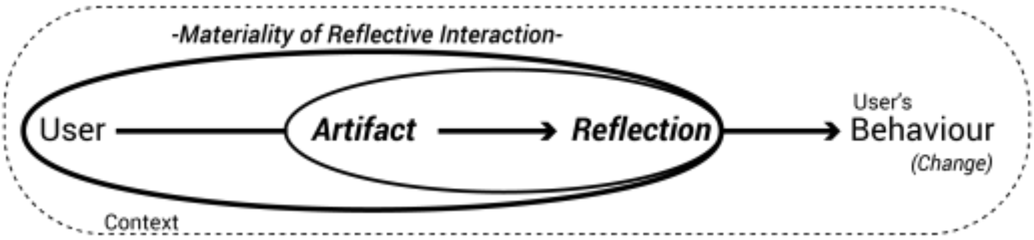

Figure 8: Materiality of Reflective Interaction

Conclusion Remarks

Smart artifacts have been defined in literature as a category of physical artifacts augmented with sensors and other actuators and are connected to the Internet. They are able to capture and monitor human or environment-driven information, for instance regarding human activity, energy consumption and etc. then to provide feedback.[71] As a part of this stream of research, many works have investigated on technologies to support or persuade behaviors, or how to build strategies for behavior change and how to bridge the gap between HCI and behavioral theories. [72]

However, it seems there is still a need to better understand how connected or smart artifacts can contribute to a conscious and mindful behavior change, in particular through provoking thoughts and reflection. This is a relatively new topic within the HCI community. Despite growing interest and available technologies, the implication for designing smart products able to stimulate reflection in user has been limited to the field of data visualization on mobile apps, websites and wearable devices or environmental installations. Perhaps this is due to the lack of studies in design of tangibility and materiality of interaction between users and smart artifacts. In which the latter is able to mediate reflection towards behavior change.

As an attempt to summarize the content of this paper, we present the following model. In this model we suggest to focus on the evocative role of artifacts and that artifacts can be designed to support reflection. Then we introduce two notions of: 1) Materials for Reflection and 2) Materiality of Reflective Interaction as two ways of defining design space for designing interactive artifacts to think with (Figure 9).

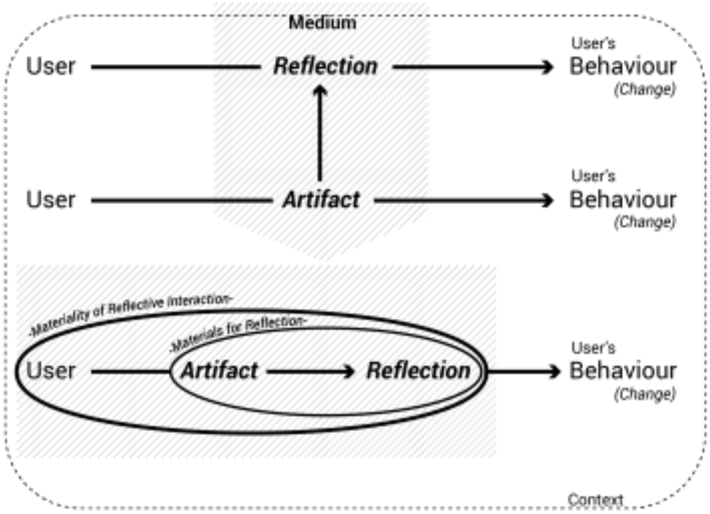

Figure 9: Design space for design of interactive artifacts to think with.

Choosing reflection as a concept for design of interactive, concrete and physical artifacts, and considering the observations and two approaches towards design of such artifacts, we conclude this paper arising some questions for future researches:

How can an interactive artifact stimulate reflection in user through tangibility and materiality of interaction? What tangible and intangible characteristics such artifacts might have? What are their behaviors? How might the context and setting influence the characteristics of interactive artifacts? What are the design ingredients of such reflective interaction?

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1 Donald Schön, *The reflective practitioner: how professionals think in action* (New York:Basic Books, 1983) pp

2 Donald Schön, "Designing as reflective conversation with the materials of a design situation", *Research in Engineering Design* 3, no. 3 (1992) 131-147.

3 Louis Bucciarelli, "Reflective practice in engineering design", *Design Studies* 5, no. 3 (1984), 185–190.

4 Jonas Löwgren and Erik Stolterman, *Thoughtful Interaction Design* (Cambridge: MIT Press, 2004) pp

5 Per Liljenberg Halstrøm, "Rhetorical Tools for Discovery and Amplification of Design Arguments", *Design Issues* 33, no. 1 (2017) 3-16

6 Sherry Turkle, *Evocative Objects: Things we Think with*, (Cambridge: MIT Press, 2011)

7 Eric Baumer. 2015. "Reflective Informatics: Conceptual Dimensions for Designing Technologies of Reflection". In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'15). New York: ACM.

Sara Price, Yvonne Rogers, Mike Scaife, Danaë Stanton, Helen Neale, "Using 'tangibles' to promote novel forms of playful learning". *Interacting with computers* 15, no. 2, (2003) 169-185

Eike Falk Anderson, Leigh McLoughlin. 2007. "Critters in the classroom: a 3D computer-game-like tool for teaching programming to computer animation students". In *Proceedings of the ACM SIGGRAPH' 07 educators program Conference*. New York:ACM.

Yvonne Rogers and Henk Muller, "A framework for designing sensor-based interactions to promote exploration and reflection in play", *International Journal of Human-Computer Studies*. 64, no.1 (2006) 1-14

8 In Behavior Change Design see for example:

Sylvain Malacria, Joey Scarr, Andy Cockburn, Carl Gutwin, and Tovi Grossman.2013. "Skillometers: reflective widgets that motivate and help users to improve performance". In *Proceedings of the 26th annual ACM symposium on User interface software and technology (UIST'13)*. New York: ACM, 321-330

Feng Gao .2012. "Design for Reflection on Health Behavior Change". In *Proceedings of the ACM International Conference on Intelligent User Interface (IUI' 12)*. New York: ACM, 379-382

In the area of Sustainability and Behavior Change Design for example see:

Hrönn Brynjarsdóttir, Maria Håkansson, James Pierce, Eric Baumer, Carl DiSalvo, Phoebe Sengers. 2012. "Sustainably unpersuaded: how persuasion narrows our vision of sustainability". In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*. New York: ACM, 947-956.

Jon Froehlich, Leah Findlater, James Landay .2010. "The Design of Eco-feedback Technology", In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '10)*. New York: ACM, 1999-2007.

Heather McKinnon, "Domestic Reflections, Electric Reflections: Design Interventions Foregrounding Energy Mundanity in the Home", *Design Issues* 32, no.4 (2016): 29-39

In Critical Design see for example:

Shaowen Bardzell, Jeffrey Bardzell, Jodi Forlizzi, John Zimmerman and John Antanitis .2012. "Critical design and critical theory: The challenge of designing for provocation". In *Proceedings of the Designing Interactive Systems Conference (DIS 2012).* ACM: New York, 288-297

Anthony Dunne, Fiona Raby, *Design Noir: The Secret Life of Electronic Objects* (Basel: Birkhäuser, 2001)

Anthony Dunne, *Hertzian Tales*, (Cambridge: MIT press, 2008)

In Design Process see for example:

Schön, *The reflective practitioner: how professionals think in action*.

Löwgren and Stolterman, *Thoughtful Interaction Design*.

Barry Wylant, "Design and Thoughtfulness" *Design Issues* 32, no.1 (2016): 72-82

Per Liljenberg Halstrøm, "Rhetorical Tools for Discovery and Amplification of Design Arguments", 3-16

Rowanne Fleck, Geraldine Fitzpatrick .2010. "Reflecting on Reflection: Framing Design Landscape". In *Proceedings of the 22nd Conference of the Computer-Human (CHI'10)*, Interaction Special Interest Group of Australia on Computer-Human Interaction. New York:ACM, 216-223

9 Rowanne Fleck .2012. "Designing for Reflection, Sustainability and Simplicity", Presented at: *Workshop on Simple, Sustainable living, (CHI'12)*, Austin, Texas, USA.

Eric Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, Geri Gay, "Reviewing Reflection: On the Use of Reflection in Interactive System Design".2014. In *Proceedings of the ACM Conference on Designing Interactive Systems (DIS'14)*. New York: ACM, 93–102

10 Schön, *The reflective practitioner: how professionals think in action*.

11 Kent Gustafson, Winston Bennett. *Issues and Difficulties in Promoting Learner Reflection: Results from a Three-Year Study.* Mesa: Air Force Research Laboratory, 2002. Accessed January 18, 2017. http://www.dtic.mil/dtic/tr/fulltext/u2/a472616.pdf

Fleck and Fitzpatrick, "Reflecting on Reflection: Framing Design Landscape".

12 Bernd Ploderer, Wolfgang Reitberger, Harri Oinas-Kukkonen Julia Gemert-Pijnen, "Social Interaction and reflection for behavior change", *Personal and Ubiquitous Computing* 18, no.7 (2014), 1667-1676

13 Oren Zuckerman, Ayelet Gal Oz , "Deconstructing Gamification: Evaluating the Effectiveness of Continuous Measurement, Virtual Rewards and Social Comparison for Promoting Physical Activity". *Personal and Ubiquitous Computing* 18, no.7 (2014): 1705-1719

Harri Oinas-Kukkonen, "A Foundation for the Study of Behavior Change Support Systems", *Personal and Ubiquitous Computing* 17, no. 6 (2013): 1223-1235

Corbin Reno .2016. "It Matters If My Friends Stop Smoking: Social Support for Behavior Change in Social Media. In *Proceedings of the Conference on Human Factors in Computing Systems (CHI'16),* New York: ACM, 5548-5552

Wolfgag Reitberger, Bernd Ploderer, Christoph Obermair, Manfred Tscheligi .2007. "The perCues framework and its application for sustainable mobility". In *Proceedings of International Conference on Persuasive Technology (2007)*. Berlin:Springer, vol. 4744, 92–95

Andrea Grimes Parker, "Reflection-through-performance: personal implications of documenting health behaviors for the collective". *Personal and Ubiquitous Computing* 18, no. 7 (2014) 1737-1752

14 Paul Dourish, Melissa Mazmanian .2011. "Media as material: information representations as material foundations for organizational practice". In *Proceedings of the 3rd international symposium on process organization studies*. (2011), Oxford University Press: Oxford

15 Jon Froehlich, Leah Findlater, Marilyn Ostergren, Solai Ramanathan, Josh Peterson, Inness Wragg, Weic Larson, Fabia Fu, Mazhengmin Bai, Shwetak Patel, James A. Landay, " The Design and Evaluation of Prototype Eco-feedback Displays for Fixture-level Water Usage Data".2012. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '12)*, New York: ACM, 2367–2376.

16 Michael Oduor, Tuomas Alahäivälä, Harri Oinas-Kukkonen, "Persuasive software design patterns for social influence". *Personal and Ubiquitous Computing* 18, no.7 (2014):1689-1704

Ian Li, I., Anind K. Dey, Jodi Forlizzi .2011. "Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies". In *Proceedings of the 13th international conference on Ubiquitous computing*. New York:ACM, 405-414

Manuel Dietrich, Kristof Van Laerhoven, "An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity". *Philosophies*, 1 (2016):55-67

17 Corina Sas, Alan Dix, "Designing for reflection on personal experience". *International Journal of Human-Computer Studies* 69, no.5, (2011):281-282

Corina Sas, Alan Dix .2009. "Designing for reflection on personal experience". In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Extended Abstracts (CHI EA '09)*. New York:ACM, 4741-4744

18 Rowanne Fleck and Geraldine Fitzpatrick, "Reflecting on Reflection".

19 John Dewey, *How We Think. A restatement of the relation of reflective thinking to the educative process*. (Boston: D. C. Heath, 1933)

Schön, *The reflective practitioner: how professionals think in action*.

Jennifer A. Moon, *Reflection in Learning & Professional Development*. (Abingdon, Oxon: Routledge Falmer,1999)

20 Phoebe Sengers, Kirsten Boehner, Shay David, Joseph Kaye .2005. "Reflective design". In *Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility (CC '05)*. New York: ACM.

21 William W. Gaver, Jacob Beaver, Steve Benford .2003. "Ambiguity as a resource for design". In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI' 03),* New York:ACM, 233-240

22 Phoebe Sengers, Kirsten Boehner, Shay David, Joseph Kaye .2005. "Reflective design". In *Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility (CC '05)*. New York: ACM.

23 Dewey, *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*.

Schön, *The Reflective Practitioner: How Professionals Think in Action*.

Moon, *Reflection in Learning & Professional Development*.

24 Thomas Binder, Giorgio De Michelis, Pelle Ehn, Giulio Jacucci, Per Linde, Ina Wagner, *Design Things*. (Cambridge: MIT press, 2011)

25 Harold G. Nelson, and Erik Stolterman, *The Design Way: Intentional Change in an Unpredictable World*. (Cambridge: MIT Press, 2012)

26 Herbert A. Simon, *The Sciences of the Artificial* (3rd Ed.), (Cambridge: MIT Press, 1996)

Nathan Crilly, "The roles that artefacts play: technical, social and aesthetic functions". *Design Studies* 31, no.4, (2010): 311-344

27 John Gero, "Design Prototypes: A Knowledge Representation Schema for Design", *AI Magazine* 1, no.4 (1990): 26-36

28 James J. Gibson, "The Theory of Affordances", in *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*, ed. Robert Shaw and John Bransford (Lawrence Erlbaum, 1977), 127-143

James J. Gibson, *The Ecological Approach to Visual Perception* (Boston: Houghton Mifflin, 1979)

Donald Norman, *The design of Everyday Things* (New York: Basic Books, 1988)

29 Sherry Turkle, *Evocative Objects: Things we Think with* (Cambridge: MIT Press, 2011)

30 Bill Verplank, *Interaction Design Sketchbook: Frameworks for Designing Interactive Products and Systems,* 2009. https://ccrma.stanford.edu/courses/250a-fall-2004/IDSketchbok.pdf. Accessed January 18, 2017

31 Mark Weiser, "The Computer for the Twenty-First Century". *Scientific American*, September 1991, 94-104.

Mark Weiser and John S. Brown, *Designing Calm Technology*, 1995. http://www.ubiq.com/weiser/calmtech/calmtech.htm. Accessed January 21, 2017

32 Gred Kortuem, Fahim Kowsar, Vasughi Sundramoorthy, Daniel Fitton, "Smart artifacts as building blocks for the Internet of things", *IEEE Internet Computing* 14, no.1 (2010): 44-51

Giancarlo Fortino, Antonio Guerrini, Russo W. "Agent-oriented Smart Artifacts development".2012. In *proceeding of the IEEE 16th International Conference on Computer Supported Cooperative Work in Design (CSCWD' 12),* IEEE, 907-912.

33 Marta Sabou, "Smart Artifacts: Challenges for Semantic Web Research", *Semantic Web - Interoperability, Usability, Applicability* 1 (2010): 1-5

34 Gred Kortuem, et al. "Smart artifacts as building blocks for the Internet of things"

35 Manuel Dietrich, Kristof Van Laerhoven, "An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity".

36 Bruce Sterling *Shaping Things* (Cambridge: MIT Press, 2005)

37 William J. Clancey *Situated Cognition* (Cambridge: Cambridge University Press,1997)

38 John S. Gero, "Conceptual designing as a sequence of situated acts," in *Artificial Intelligence in Structural Engineering*, ed. I. Smith (Berlin: Springer, 1998), 165-177

39 Giancarlo Fortino, Antonio Guerrini, Russo W. "Agent-oriented Smart Artifacts development"

40 Luigi Atzori, Antonio Iera, Giacomo Morabito "From "Smart Objects" to "Social Objects": The Next Evolutionary Step of the Internet of Things", *IEEE Communication Magazine* 52 (2014), 97-105

Julian Bleeker, *A Manifesto for Networked Objects, Cohabiting with Pigeons, Arphids and Aibos in the Internet of Things.* 2006. Accessed January 24, 2017 http://nearfuturelaboratory.com/files/WhyThingsMatter.pdf.

David Rose, *Enchanted Objects: Design, Human desire and the Internet of Things* (New York: Scribner, 2014)

41 Glen Allmendinger, Ralph Lombreglia "Four Strategies for the Age of Smart Services", *Harvard Business Review*, October, 2005, 131– 145, accessed January 2017, https://hbr.org/2005/10/four-strategies-for-the-age-of-smart-services

42 Max Mühlhäuser, "Smart Products: An Introduction", In *Constructing Ambient Intelligence*, eds. Mühlhäuser M., Ferscha A., Aitenbichler E. in the series of *Communications in Computer and Information Science* 11 (Berlin: Springer, 2008): 158-164

43 Lars E. Janlert, Erik Stolterman, "The meaning of interactivity - Some Proposals for Definitions and Measures" *Human–Computer Interaction* 00 (2016): 1-36

44 For mobile and wearable devices see for example:

Zachary Pousman, John Stasko .2006. "A Taxonomy of Ambient Information Systems: Four Patterns of Design". In *Proceedings of* *the working conference on Advanced visual interfaces (AVI'06)*, New York: ACM, 67-74.

Ian Li, I., Anind K. Dey, Jodi Forlizzi "Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies"

Manuel Dietrich, Kristof Van Laerhoven .2014. "Recall your Actions! Using Wearable Activity Recognition to Augment the Human Mind". In *Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing (Ubicomp '14 Adjunct)*. New York: ACM, 1347-1353

Jeni Paay, Jesper Kjeldskov, Mikael Skov, Umachanger Brinthaparan, Nirojan Srikandarajah, Dimitris Raptis .2015. "QuittyLink: A Mobile Application That Helps People Quit Smoking." In *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct*. New York: ACM, 599-606

Manuel Dietrich, Kristof Van Laerhoven, "An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity"

Dong Tao, "Designing Reflective User Experience with Social and Ubiquitous Computing Technologies" (PhD diss., University of Michigan, 2015).

For environmental installations see for example:

Lars Hallnäs, Johan Redström, "Slow Technology, Designing for Reflection". *Personal and Ubiquitous Computing* 5, no.3 (2001): 201-212.

45 Brian Shackel, "Ergonomics for a Computer" *Design* 120 (1959): 36–39

Brian Shackel, "The concept of usability". In *Visual Display Terminals*, ed. J. Bennet, et al., (Englewood Cliffs, NJ: Prentice-Hall, Inc., 1984): 45–88

46 Renee Wever, Jasper van Kuijk, Casper Boks, "User- Centred Design for Sustainable Behavior", *International Journal of Sustainable Engineering* 1, no.1 (2009): 9-20

47 Donald Norman, *The design of Everyday Things*.

Donald Norman, *The Design of Future Things* (New York: Basic Books, 2007)

48 James J. Gibson, "The Theory of Affordances", 127-143

Donald Norman, *The design of Everyday Things*.

Jon Kolko, *Thoughts on Interaction Design* (Burlington: Morgan Kaufmann, 2011)

49 Dan Lockton, David Harrison, Neville A. Stanton "The Design with Intent Method: a design tool for influencing user behavior". *Applied Ergonomics* 41, no. 3 (2010): 382-392.

50 Dan Lockton "The Design with Intent Method".

51 Kristina Niedderer, "Designing Mindful Interaction: The Category of Performative Artifact" *Design Issues* 23, no.1 (2007): 3-17.

Kristina Niedderer .2013. "Mindful Design as a Driver for Social Behaviour Change". Presented in the *International Congress of Inernational Association of Societies of Design Research (IASDR),* Tokyo, Japan.

53 Mikael Wiberg, Erica Robles "Computational compositions: aesthetics, materials, and interaction design" *International Journal of Design* 4 no.2 (2010): 65-76.

54 Hendrik N. J. Schifferstein, Paul Hekkert "Introducing Product experience" in *Product Experience*, eds. Schifferstein H. N. J.

and Hekkert P. (Amsterdam: Elsevier, 2008), 1-8

55 For effect of colors see for example:

Prabu Wardono, Haruo Hibino, Shinichi Koyama "Effects of Interior Colors, Lighting and Decors on Perceived Sociability, Emotion and Behavior Related to Social Dining". *Procedia - Social and Behavioral Sciences* 38, (2012): 362-372.

Jamie Hyodo "Can Colors Make Me Happy? The Effect of Color on Mood: A Meta-Analysis". *Advances in Consumer Research* 39 (2011): 858-868.

56 For effect of sounds see for example:

René Van Egmond (2008) "The Experience of Product Sounds," in *Product Experience*, eds. H. N. J. Schifferstein and P. Hekkert, (Amsterdam: Elsevier, 2008), 69-89

57 Rajeev Sharma, Vladimir I. Pavlovic, Thomas S. Huang .1998. "Toward Multimodal Human-Computer Interface". In *Proceedings of the IEEE* 86, no.5 (1998): 853-869.

Steven Houben, Connie Golsteijn, Sarah Gallacher, Rose Johnson, Saskia Bakker, Nicolai Marquardt, Licia Capra, Yvonne Rogers .2016. "Physikit: Data Engagement Through Physical Ambient Visualizations in the Home". In *Proceedings of the Conference on Human Factors in Computing Systems (CHI' 16)* New York: ACM, 1608-1619.

58 William W. Gaver, "Auditory interfaces" in *Handbook of Human-Computer Interaction*, eds. Martin G. Helander, Thomas K. Landauer and Prasad Prabhu (Amsterdam: Elsevier, 1998), 1003-1041

Gregory Kramer, *Auditory Display: Sonification, Audification, and Auditory Interfaces* (Boston: Addison-Wesley Longman Publishing Co., Inc., 1993)

William W. Gaver "Auditory Icons: Using Sound in Computer Interfaces", *Human-Computer Interaction* 2, no.2 (1986): 167-177

59 Saskia Bakker, Elise van den Hoven, Berry Eggen, "Peripheral interaction: characteristics and considerations," *Personal and Ubiquitous Computing* 19, no.1 (2015): 239-254.

60 Lars Hallnäs, Johan Redström, "Slow Technology, Designing for Reflection".

61 Martin Siegel, Jordan Beck "Slow Change Interaction Design", *IX Interactions*, January - February 2014, 28

62 Manuel Dietrich, Kristof Van Laerhoven, "Recall your Actions! Using Wearable Activity Recognition to Augment the Human Mind".

Manuel Dietrich, Kristof Van Laerhoven, "An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity"

63 Peter-Paul Verbeek, "Materializing morality design ethics and technological mediation," *Science, Technology & Human Values* 31, no.3 (2006) 361-380

Paul Dourish, *Where the Action is*.

64 Hiroshi Ishii, Brygg Ullmer .1997. "Tangible bits: towards seamless interfaces between people, bits and atoms," in *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems (CHI'97),* New York: ACM, 234-241

Hiroshi Ishii, Dávid Lakatos, Leonorado Bonanni, Jean-Baptiste Labrune, "Radical Atoms: Beyond Tangible Bits", *Interactions* 19, no.1 (2012):38-51

Eva Hornecker, Jacob Buur .2006. "Getting a grip on tangible interaction: a framework on physical space and social interaction," in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'06)* New York: ACM, 437-446.

Orit Shaer, Eva Hornecker, "Tangible user interfaces: past, present, and future directions", *Foundations and Trends in Human-Computer Interaction* 3, no. 1–2 (2010): 1-137.

Ali Mazalek, Elise van den Hoven, "Framing Tangible Interaction Frameworks", *Artificial Intelligence for Engineering Design, Analysis and Manufacturing* 23, no.3 (2009): 225-235.

65 Dourish, *Where the Action is*, 161.

66 Ryan Aipperspach, Ben Hooker, and Allison Woodruff, "Data Souvenirs: Environmental psychology and reflective design". *Intenrnational Journal of Human-Computer Studies* 69, no.5, (2011): 338-349

Anja Thieme, Jayne Wallace, James Thomas, Ko Le Chen, Nicole Krämer, Patrick Olivier, "Lovers' box: Designing for reflection within romantic relationships". *Intenrnational Journal of Human-Computer Studies* 69, no.5, (2011): 283-297

Doménique van Gennip , Elise van den Hoven , Panos Markopoulos .2015. "Things That Make Us Reminisce: Everyday Memory Cues as Opportunities for Interaction Design", In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI'15),* New York:ACM, 3443-3452

Ine Mols , Elise van den Hoven , Berry Eggen .2016. "Technologies for Everyday Life Reflection: Illustrating a Design Space". In *Proceedings of the Tenth International Conference on Tangible, Embedded, and Embodied Interaction* (*TEI '16*), New York:ACM, 35,61

67 Lars E. Janlert, Erik Stolterman "Faceless Interaction – A Conceptual Examination of the Notion of Interface: Past, Present, and Future", *Human Computer Interaction* 30, no. 6 (2015): 507-539
Ishii, et al. "Radical Atoms: Beyond Tangible Bits".

68 Mikael Wiberg, Hiroshi Ishii, Paul Dourish, Anna Vallgårda, Tobie Kerridge, Petra Sundström, Daniela Rosner, Mark Rolston, "Materiality Matters – Experience Materials", *ACM Interactions*, March-April 2013, 54.

69 Sherry Turkle, *Evocative Objects: Things we Think with.*

70 Mikael Wiberg, "Interaction, New Materials & Computing: Beyond the Disappearing Computer, Towards Material Interactions", *Materials & Design,* 90 (2016)1200-1206.

71 Manuel Dietrich, Kristof Van Laerhoven, "An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity".

72 BJ Fogg, *Persuasive Technology: Using Computers to Change What We Think and Do,* (San Francisco: Morgan Kaufman, 2003)

Robert B. Cialdini, *Influence: The Psychology of Persuasion* (New York: HarperBusines, 2007)

Stephen Clune, "Design for Behavioural Change", *Journal of Design Strategies*, 4, no.1 (2010): 68-75.

Eric B. Hekler, Predrag Klasnja, Jon E. Froehlich, Matthew P. Buman .2013. Mind the Theoretical Gap: Interpreting, using and developing behavioral theory in HCI. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'13)*. New York: ACM, 3307-3316

Felix Lossin, Allister Loder, "Energy Informatics for Behavioral Change", *Computer Science – Research and Development* 31, no. 3 (2016): 149-155

"WISE THINGS": WHEN SMART OBJECTS STIMULATE REFLECTION

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ABSTRACT

Despite a variety of purposes for designing smart objects (SOs), design of such artifacts with the purpose of provoking people's thoughts and reflection on complex issues (e.g. environmental and societal) is still little explored. In fact, the ability of SOs to recall information about people's behaviors helps them to reflect on the consequences.
As an attempt, this paper introduces the concept of Wise Thing as a category of such smart objects, with augmented properties of being Deliberative, Reflectional, Experiential, and Communicative.

KEYWORDS

Smart Objects, Reflection, Behavior Change Design

1. INTRODUCTION

The increasing use of computing technologies and the Internet connectivity are changing people's way of living. This phenomenon in various academic literature and commercial media takes several names, such as Ubiquitous Computing (Weiser, 1996), Internet of Things (Ashton, 2009), Connected Homes (Ericsson, 2015) and has been also largely debated in the Design and Human-Computer Interaction (HCI) literature (Dourish, 2004a; Lowgren and Stolterman, 2004). Many attention have been put on how human interactions with connected and computing objects can stimulate human behavior (Norman, 2007; Norman, 1988; Fogg, 1998; 2003; 2009; Moggridge, 2007; Verplank, 2009; Kuniavsky, 2010, Dix, 2009). Further, Captology explains how computers can foster and facilitate behavior change through application of specific techniques and methods (Fogg, 2003; Cialdini, 2007; Clune, 2007; Wendel, 2014). The human-product interaction has been also widely explored in User-Centered Design, where the nature, quality and elements of this interaction are investigated (e.g. Vredenburg, et. al., 2002; Preece et al., 2002) and extended to exploring cognitive mechanisms in order to improve usability and user experience (Shackel, 1984; Baber and Stanton, 1996; Norman, 2007). Current Design literature on behavior change is mostly focused on using tools, processes and methods to change or maintain a behavior based on user's predefined goals. This approach often faces some difficulties, especially when it is applied to changing some behaviors (e.g. energy or water consumptions) that might contribute to the environmental problems, such as climate change and natural resource depletion.

Smart Objects (SO) have been defined as a category of computing artifacts augmented with sensors and other actuators, connected to the Internet, able to capture and monitor user or environment-driven data and to provide feedback (e.g. Dietrich and Laerhoven, 2016). So, the design of Smart Objects (SOs) concerns also the quality of interactions with the user and the environment.

Despite growing interest and available technologies, the design of smart products that stimulate user's reflection has been limited to the field of data visualization on mobile apps, websites and wearable artifacts (Ian, et. al. 2011, Dietrich and Laerhoven, 2014; 2016) or environmental installations (Hallnäs and Redström, 2001). Perhaps this is due to the lack of studies regarding the physical form and also tangible properties of interaction with connected artifacts able to promote reflection.

SOs run with the same physical, smart and connectivity components as those of the artifacts able to stimulate reflection, and they seem to be made of similar materials and produced with similar techniques. So, what makes the difference mostly relies on the way they are designed.

As an attempt to overcome this research gap, the focus of the paper is to propose those features of smart objects that enable them to stimulate reflection in user.

To this end, first we briefly discuss about the relation between behavior change and reflection in HCI. Then, we provide literature about characteristics of SOs in order to introduce the concept and properties of Wise things.

2. REFLECTION WITH THE PURPOSE OF BEHAVIOR CHANGE IN HCI

Reflection as a way of thinking, enables the review and merging previous experiences and events to help a better understanding or to gain some sort of insight. Schön (1983) states that *reflection is a type of 'thinking about' that enables a kind of problem solving involving the construction of an understanding and reframing*. Other authors specifically consider reflection as the final aim of the design process or reflection as a tool to stimulate a new way of thinking (Gaver et al., 2003).

The notion of reflection has been of great interest to the HCI community, where technology enable reflection and critical thinking as a support for learning (Price et al., 2003; Anderson et al., 2007) or for playing (Rogers and Muller, 2006). In these domains, 'reflection' refers to the action of reflecting on information provided and being conscious about the consequences of an action or behavior (Fleck, 2012; Baumer, et. al. 2014). Data are visualized to bring into mind memories and experiences. Sengers et al. (2005) in particular reflect on the role of technology by introducing 'Reflective Design' as *a practice, which combines analysis of the ways in which technologies reflect and perpetuate unconscious cultural assumptions, with design, building, and evaluation of new computing devices that reflect alternative possibilities*. This emphasizes the role of critical thinking as an essential tool to allow people make conscious value choices in their attitudes and practices.

The idea of using the features of an artifact to stimulate, drive or shape human behavior has been the subject of researches according to different approaches and perspectives, such as in Design With Intent (Lockton, et. al, 2010) or Performative Objects (Niedderer, 2007). Furthermore, the sensorial properties of artifacts, such as attributed color, material texture and sound, can shape perceptions and experiences, and surely affect human behaviors (Schifferstein and Hekkert, 2008; Prabu, et. al., 2012; Wardano et al., 2012; Hyodo, 2011; van Egmond, 2008). Further computing technologies have been used for user behavior change (Norman 1988; 2007). Wherein human cognitive and psychological factors have been entered into Design Research, such as the concepts of affordance, constraint and feedback (e.g. Kolko, 2011).

Despite growing interest and availability of these technologies, designing for reflection is still in its early stages and has been identified as research opportunity within Design research (Baumer, et. al. 2014). Even though tangible user interfaces (TUI) are becoming diffused in SOs, there is still a lack of studies regarding the exploration of the novel forms of interaction that can promote reflection. This actually can open discussions around the ways smart objects stimulate reflection in user, so they become are not be shifts the paradigm from Smart Objects to Wise things.

3. FROM SMART TO WISE THINGS

Emerging technologies –near-field communications, real-time localization and generally embedded sensors– have enabled a range of computationally enhanced and Internet-connected devices, commonly called "smart objects" a.k.a "connected artifacts". They can sense, log and interpret events in their context and can interact and exchange information with other parties, such as other smart devices and users (e.g. Kortuem, et al., 2010; Fortino, G., Guerrini A., Russo W., 2012).

Smart objects have been explored and defined in various research fields, such as business, ambient intelligent and web semantics (Marta Sabou, 2010; Kortuem, et al. 2010) as being: 1) **Reactive:** smart objects can understand events in a given physical representation; 2) **Proactive:** smart objects can act autonomously and control the situation; 3) **Preemptive:** smart objects can predict errors and faults in order to remove unpleasant surprises for user; 4) **Interactive:** smart objects can converse and interact with the user in terms of input, output and feedback in a simple and intuitive way.

With respect to the HCI researches that have investigated on the ability of smart objects to learn human behaviors and actions, and act autonomously in order to simplify activities, we assume those abilities are able to offer an opportunity of influencing reflective behavior of users. The ability of artifacts to provoke peculiar thoughts and reflections helps and guides users almost autonomously to make conscious decisions, instead to follow fixed and pre-defined rules and steps. This is also related to the ability of products to not only support people to have an easier life but only to have a better quality of life (Schifferstein, Özcan, Rozendaal, 2015).

To this end, in this paper we describe the four augmented features of Wise things building upon the features that characterize the analogue objects and the SOs, as illustrated in Figure 1. Similar to the augmented features that enable an object to become 'smart', this augmentation process transforms an SO into a 'Wise' Object.

Although the description of these particular interactions is out of the scope of this paper, here we will introduce the four possible augmented features that might create the ground for designing the artifact and its interactions.

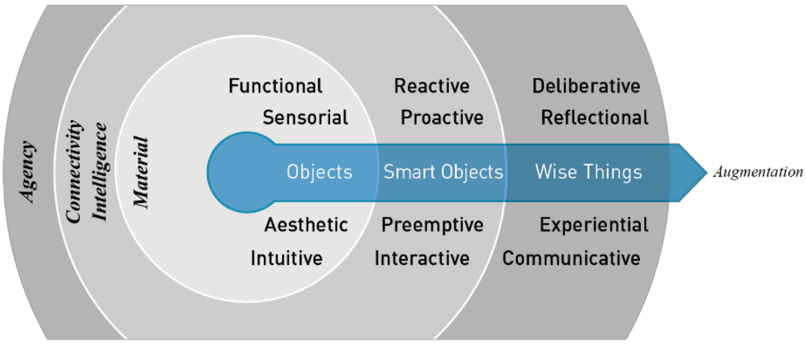

Figure 1. From an analogue object to a wise thing

3.1 Deliberative

Wise Thing is deliberative because it constructs their internal beliefs and opinions. A deliberative reasoning enables to hypothesize possible outcomes and to make decisions. It is related to the situated agents' reflective way of reasoning, as defined in the AI and multi-agent systems (MAS) studies (Gero and Kannengiesser, 2003). Being Deliberative is one of the wise thing feature that enables the construction and modification of internal concepts, beliefs and goals based on the previous experiences and perceptions.

3.2 Reflectional

This feature evokes thoughts and reflections in user through providing peculiar tangible feedbacks. It is related not only to the physical forms of artifact but also to the temporal forms (Vallgårda and Redström 2014).

Since, Wise Things perform both internal and external actions similar to any other situated agents, the external actions which are tied to the user interface, represent crucial factors concerning the Reflectional property. This is mostly because user perceives only external actions. These complex feedbacks, as perceived by user, demonstrate radical or incremental changes in the wise things interface and external structure, such as changes in form, texture and color, are as a result of the Reflectional feature.

3.3 Experiential

Research has shown that the experiment with physical artifacts can enhance the reflection and increase awareness (e.g. Hornecker and Buur, 2006). Accordingly, a wise thing is Experiential, that has the ability of engaging the user into experimentation and exploration. Likewise, it is assumed that provoking user's reflection on personal data becomes more effective if the perception of information is not just limited to the user's visual perception, but also integrates the tangible interaction with information. This means the interaction should involve other sensorial capacities rather than just visual (e.g. Ullmer and Ishii, 1997; Shaer and Hornecker, 2010; Rinott, 2013; Houben et. al., 2016). In addition, the tangible representation of data, conversely of numerical data visualization, leaves open the interpretation of the information.

The Experiential feature of wise things includes important drivers of reflection such as openness to interpretation and playfulness of engagement and exploration.

3.4 Communicative

Debates on the communicative character of computing technology is not new. Computers as constructive tools have been used for the purpose of learning in educational contexts (Papert and Kay, 1968; Kay, 1972) or for expression and communications of algorithms and models in network communications (Dourish, 2004b). In addition, in every design context, the Communication, allows artifacts to deliver the designers' intention as a message to the users, where *the sender* is the designer, who intends to transmit a particular *message* to a *receiver* (the user) through a physical artifact as a *medium* (Crilly et. al., 2008; Varduoli, 2015). According to this interpretation, "use" become as "writing", "reading" and encoding the message (Crilly et. al., 2008) and the medium modulation becomes essential because it is a particular form of transformation. Modulation is also defined as the carrier of information or the carrier of meaning in terms of embodied interaction (Dourish, 2004a). The modulation/communication/transformation process between wise things and users creates a loop, wherein wise things do not merely convey and transform the message, but are also able to receive and interpret them and resend the information to the user via encoding and decoding. Wise things together with users participate in the process and are able to redesign the artifact and personalize the "text".

4. DISCUSSION AND CONCLUSION

Instead of designing artifacts with aiming to change people's behavior, we can consider the ability of artifacts to make people aware about environmental and societal problems and help them to reflect and make conscious decisions. Wise Things are conceived and can be designed for such purpose: they are distinguishable from existing smart and connected artifacts because they are Deliberative, Reflectional, Experiential and Communicative agents of reflection. This ability of Wise Things can find applications in many contexts wherein provoking thoughts and reflective practices are essential to learning and improving, such as organizational and educational settings.

This paper is intended as a contribution towards this direction and debating on the properties of these objects and reflecting on the consequences of their use. We hope to contribute to the ways that these four augmented characteristics (Deliberative, Reflectional, Experiential, Communicative) can guide design of the physical and concrete features of connected artifacts that promote reflection with the purpose of behavior change. This paper could stimulate future studies on wise things' forms, and their behaviors that enable such an interaction able to stimulate reflection.

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REFERENCES

Anderson, E., F., McLoughlin, L. (2007). *Critters in the classroom: a 3D computer-game-like tool for teaching programming to computer animation students*. In: Proceedings of the ACM SIGGRAPH 2007 educators program Conference, pp. 7.

Ashton, K., (2009). That 'Internet of Things' Thing, in the real world things matter more than ideas. *RFID J*. pp. 1-2.

Baber, C., Stanton, N.A., (1996). Human error identification techniques applied to public technology: predictions compared with observed use. *Applied Ergonomics* 27 (2), 119–131.

Baumer, E. P. S., Khovanskaya, V., Matthews, M., Reynolds, L., Schwanda Sosik, V., & Gay, G. (2014). *Reviewing Reflection: On the Use of Reflection in Interactive System Design*. In Proceedings of the 2014 Conference on Designing Interactive Systems (pp. 93–102). New York, NY, USA: ACM.

Cialdini, R. B. (2007). *Influence: The Psychology of Persuasion*. New York: HarperBusines.

Clune, S. (2010). Design for Behavioural Change, *Journal of Design Strategies* 4, 68-75.

Crilly, N., Good, D., Matravers, D., Clarkson, P. J. (2008). Design as communication: exploring the validity and utility of relating intention to interpretation. *Design Studies* 29(5), 425 – 457.

Dietrich M., Van Laerhoven K. (2014). *Recall your Actions! Using Wearable Activity Recognition to Augment the Human Mind*. In Proceeding of Ubicomp '14 Adjunct. Seattle, Wa, Usa.

Dietrich M., Van Laerhoven K. (2016). An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity. *Philosophies*, vol:1, 55-67

Dix A. (2009). Human-computer Interaction. In L. Liu, M. T. Özsu (Eds.) *Encyclopedia of database systems* (pp 1327-1331): Springer, US.

Dourish P. (2004a), *Where the Action is*. Cambridge: MIT Press.

Dourish. P. (2004b). What we talk about, when we talk about context. *Personal and Ubiquitous Computing* 8 (1), 19-30.

Ericsson Consumer Insight Summary Report June 2015. https://www.ericsson.com/res/docs/2015/consumerlab/ericsson-consumerlab-connected-homes.pdf, Last access July 2 2016.

Fleck R., Fitzpatrick G. (2010). *Reflecting on Reflection: Framing Design Landscape*. In Proceedings of the 22nd Conference of the Computer-Human Interaction, Special Interest Group of Australia on Computer-Human Interaction, 216-223.

Fleck R. (2012). *Designing for Reflection, Sustainability and Simplicity*, Presented at: Workshop on Simple, Sustainable living, CHI'12, Austin, Texas.

Fogg, B. J. (1998). *Persuasive computers: Perspectives and research directions*. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems 225–232.

Fogg, B. J. (2003). *Persuasive Technology: Using Computers to Change What We Think and Do*. San Francisco: Morgan Kaufman.

Fortino G., Guerrini A., Russo W. (2012). *Agent-oriented Smart Artifacts development*. In proceeding of the 16th International conference on Computer Supported Cooperative Work in Design, 907-912.

Gaver, W. W., Beaver, J., Benford, S. (2003). *Ambiguity as a resource for design*. In Proceedings of ACM CHI'3 Conference on Human Factors in Computing Systems. 233-240

Gero, J., Kannengiesser, U. (2003). *Function-Behavior-Structure: A model for social situated agents*. Workshop on Cognitive Modeling of Agents and Multi-Agent Interactions, International Joint Conference on Artificial Intelligence 101, 107.

Hallnäs L., Redström J. (2001). Slow Technology, Designing for Reflection. *Personal and Ubiquitous Computing*, 5(3), 201-212.

Hornecker, E., Buur, J. (2006). *Getting a grip on tangible interaction: a framework on physical space and social interaction*. In Proceedings of the SIGCHI conference on Human Factors in computing systems, pp. 437-446.

Hyodo J. (2011). Can Colors Make Me Happy? The Effect of Color on Mood: A Meta-Analysis. *Advances in Consumer Research* 2, 858-868.

Ishii, H., Ullmer, B. (1997). *Tangible bits: towards seamless interfaces between people, bits and atoms*. In Proceedings of the SIGCHI conference on Human factors in computing systems, 241.

Kay, A. C. (1972). *A Personal Computer for Children of All Ages*. In Proceeding of ACM'72, Annual Conference. 1, 1.

Kolko, J. (2011). *Thoughts on interaction design*. Elsevier (second Ed.).

Kortuem, G., Kowsar, F., Fitton, D., Vasughi, S. (2010). Smart artifacts as building blocks for the Internet of things, *Journal of Internet Computing*, *IEEE*, 14(1), 44 – 51.

Kramer, G. (1993). *Auditory Display: Sonification, Audification, and Auditory Interfaces*. Perseus Publishing.

Kuniavsky, M. (2010). *Design of Smart Things*. Morgan Kaufmann.

Li, I., Dey, A., Forlizzi, J. (2011). *Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies*. In Proceedings of the 13th international conference on Ubiquitous computing .405-414

Lockton, D., Harrison, D., Stanton, N. A. (2010). The Design with Intent Method: a design tool for influencing user behaviour. *Applied Ergonomics*. 41 (3), 382-392.

Moggridge, B. (2007), *Designing Interactions*, Cambridge: MIT Press.

Niedderer, K. (2007). Designing Mindful Interaction: The Category of Performative Artifact. *Design Issues*, 23(1), 3-17.

Norman, D., The design of Everyday Things, 1988. Basic Books.

Norman, D., The Design of Future Things, 2007. Basic Books.

Ortin, F., Cueva, J. M. (2003). Non-restrictive computational reflection. *Journal of Computer Standards & Interfaces*. 25, 241-251.

Prabu, W., Haruo, H., and Shinichi K. (2012). Effects of Interior Colors, Lighting and Decors on Perceived Sociability, Emotion and Behavior Related to Social Dining. *Procedia - Social and Behavioral Sciences* 38, 362–372.

Preece, J., Rogers, Y. and Sharp, H., (2002). *Interaction design: beyond human-computer interaction*. New York: John Wiley & Sons.

Price, S., Rogers, Y., Scaife, M., Stanton, D., Neale, H., (2003). Using 'tangibles' to promote novel forms of playful learning. *Interacting with computers* 15, 169-185

Rinott M., Geiger S., Gal-Or E., Or L. (2013). *Cubes*. In Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, pp. 397-398. ACM.

Rogers, Y., Muller, H. (2006). A framework for designing sensor-based interactions to promote exploration and reflection in play. *International Journal of Human-Computer Studies*. 64, 1-14

Sabou, M., (2010). Smart Artifacts: Challenges for Semantic Web Research, Semantic Web – Interoperability. *Usability, Applicability* 1, 1–5.

Schifferstein H. N. J., Özcan E., Rozendaal M. C., *Towards the maturation of design: From smart to wise products*. In Proceeding of DesForm Conference (2015), Milan, Italy.

Schifferstein, H. N. J., Hekkert, P. (2008). *Product experience*. Amsterdam, the Netherlands: Elsevier.

Schön D. (1983). *The reflective practitioner: how professionals think in action*. Basic Books, New York.

Sengers P., Boehner K., David S., Kaye J., (2005). *Reflective design*. In Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility, 2005, Aarhus, Denmark

Shackel, B. (1984). The concept of usability. In: J. Bennet, et al., (Eds) *Visual display terminals*. Englewood Cliffs, NJ: Prentice-Hall, Inc., 45–88.

Shaer O., and Hornecker E. (2010). Tangible user interfaces: past, present, and future directions, *Foundations and Trends in Human-Computer Interaction* 3, no. 1–2: 1-137.

Van Egmond, R. (2008). The experience of product sounds. In H. N. J. Schifferstein & P. Hekkert (Eds.), Product experience (pp. 69-89). Amsterdam, the Netherlands: Elsevier

Vardouli, T., (2015). Making use: Attitudes to human-artifact engagements, *Design Studies* 41, 137-161

Verplank, B. (2009) *Interaction Design Sketchbook*: *Frameworks for designing interactive products and systems*. https://ccrma.stanford.edu/courses/250a-fall-2004/IDSketchbok.pdf. Last access July 2 2016.

Vredenburg, K., Mao, J., Smith, P. W., Carey, T. (2002): *A survey of user-centered design practice*. In: L. Terveen (Eds.) Proceedings of the ACM CHI' 02 Conference on Human Factors in Computing Systems Conference, Minneapolis, Minnesota. pp. 471-478.

Weiser M., Brown S., (1996). *Designing Calm Technology*, Xerox PARC.

Wendel, S., (2014). *Designing for behavior change: Applying psychology and behavioral economics*. O'Reily Media, Sebastopol, CA, USA.

Zuckerman, O., Gal Oz A., (2014). Deconstructing gamification: evaluating the effectiveness of continuous measurement, virtual rewards and social comparison for promoting physical activity. *Personal and Ubiquitous*.

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Designing Things & Places for Reflections:

Connecting people, places and (smart) objects in the Social IoT

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Abstract

Sherry Turkle in her book, *Evocative Objects*, points out that we often consider objects as useful or aesthetic, but rarely count them as our companions or as provocations to thoughts. Indeed, according to the distributed cognition theory, our cognitive activities are considerably influenced by and are also the product of our interactions with, the external stimuli, such as everyday objects.

Within the vast category of these external stimuli, we can also include our indoor places: the architectural three-dimensional space, where we spend our times within, doing various activities, using numerous objects, interacting with people. Considering space as a factor that influences our thinking.

In this book chapter we present a relational approach to the design of the social IoT (SIoT). We do this by we talking specifically about "reflective thinking" and we describe how it is situated in relation to computer-enhanced and smart place. Further we describe how it is related to people's activities and smart objects within that place. In this framing, we approach SIoT as a technical enabler for designing places that support reflective activity. We see this book chapter as another contribution to the stream of activity-oriented design researches.

We will provide models intended to clarify the relationships between the external factors that influence reflective thinking in a place. Then we suggest some guidelines for designing "Places" for reflective thinking.

In short, the aim of our work as presented in this chapter is to spark a conversation and discussion in HCI/Interaction Design about what designing places for supporting reflection using Social IoT could refer to. In doing so, we suggest 1) that a central dimension in design of such places is the study and implementation of *relations* among the components within it: people, their activities, and objects, and accordingly we suggest 2) that a central theoretical contribution from our work is to conceptualize the social IoT as not only a technical platform, but rather as a relational technology that enables new places for reflection.

1. Introduction

Our thinking relies –to a large extent– on our interactions with objects and things. We use objects, spaces, and materials for our reflective processes. Further on, the things we are surrounded with, are increasingly computational, smart, networked and interconnected. Accordingly, our "thinking" is increasingly influenced by interactions with such computing and interactive objects and spaces, as well as with the people we are connected to (Dalton, et al., 2016). Therefore, our thoughts are increasingly part of larger interconnected systems – sometimes referred to as the Social Internet of Things (SIoT).

But how can spaces serve as scaffolds for thinking? And how do we design the Social Internet of Things as an enabler of spaces for reflection? Further how can we design such spaces as part of bigger social networks of connected objects and things in the so-called Social Internet of Things? And how do these things stand in relation to us in these increasingly digitalized networks of things? For sure, the Internet of Things (IoT) comes with the promise of a nearby future filled with networked smart objects and environments. But how can we align one such technology-driven agenda with a vision of how smart objects not only bring computation to the environments they are part to, but also how such computational objects and things might be designed both in relation to the places that constitute our everyday environment, and to our everyday thinking?

Designing for thinking, and in particular for "reflective thinking" is consequently a complex task, mostly because, it is in relationships with many external things such as artifacts, spaces, people and it is also interrelated with other activities.

In the area of Human-Computer Interaction (HCI), "reflection" often refers to the action of thinking about the information provided by computing artifacts, in order to be informed about an action or behavior and take course of actions to modify or change it in the future (Fleck 2012). Moreover, social interactions have relevant role to foster reflection as they create that possibility of talking with other people about experience. Talking with other people about experiences, help to recall memories not only about the action, but also objects and places (Baumer 2014).

[HCI and Interaction design and UCD (User Centered Design), have long traditions in focusing on use and users in designing interactive systems and artifacts… (Kaptelinin and Bannon, XX, XXXX)] Maybe also relate this to "contextual design"? (in terms of established approaches that recognizes the importance of designing interactive systems also in relation to social and physical context (place)?

The continuous development of social media platforms, in combination with the growing interest in the Internet of Things (IoT) also suggest technological developments towards a Social Internet of Things, wherein, smart and connected devices can participate in their own social network, and wherein the IoT devices can have their own social existence. For this development we need to develop a deliberate design rationale for how such networks could support user's thoughts and reflection. Since the diffusion of Internet connectivity across devices and social networks, brought new possibilities of designing new kinds of objects and spaces, it has also brought new challenges to the design community. This new category of devices called IoT or smart devices (Ashton, 2009) makes designers to not only think about design of functionalities, experiences and ease of usage, but also think about the network and social interactions of these computational and smart artifacts (Azori et. al. 2012; Robbins, et. al. 2016).

As to address these matters we take a historical approach to interaction design, and in particular in relation to the advent of IoT in relation to how technology has been developed over time to also support reflective thinking. We do so by grounding our work in the history of tangible and everyday interaction with computers (Venkatesh 1996; Dourish 2004). Further, we look for theoretical grounding of our work in the theory of distributed cognition (Rogers 1997; Hollan et. al. 2000) as to better understand the interplay between people, and their relations to objects in acts of thinking, in particular the cognitive aspects of collective problem solving through social interactions, and through the use of thinks, objects and other external representations that support thinking. Here the theory of distributed cognition provide us with some theoretical ground as it deals with the *relation* between humans, objects and spaces, in a cognitive activities, processes of reflections, and as a framework for thinking about these things from a relational perective. Further, this framework extend the boundary of cognition beyond the individual brain and mind (in specific terms - distributed problem solving with the use of objects) and it enable us to address questions related to how we think together, and the role of objects in reflective processes.

In this book chapter, we first seek to frame "thinking" as a task, and how it stands in relation to many different external factors, and we do this initial framing by grounding our work in the theory of distributed cognition.

Having introduced our main notion and its theoretical grounding we then build on that as to provide a couple of models and figures that we have developed to illustrate and clarify the relations among thinking and the external factors that influence them. Following from that we suggest conclude this chapter with some guidelines for designing "Places" for thinking, followed by some implications for Social IoT.

2. Reflective thinking and Distributed Cognition Process

The theory of distributed cognition - like any other theory of cognition - seeks to describe how cognitive processes work. However, unlike other traditional cognitive theories, it considers cognitive process as a series of interactions between the individual, other people, objects and the environments in which the cognitive process takes place. It can also be applied to reflective thinking as a cognitive process, which is not only individual, but also collective and distributed. Reflection depends on many external factors such as people acting as mentors, social interaction, objects that holds memories and emotions, environments which are stimulating for reflection and so on. Reflective reasoning is a deep, slow and effortful process (Norman 1993, pp 25). It requires moments of quiet, but also the aid of external support, such as writing, computing tools, books and the aid of other people. Unlike the experiential thinking, reflective thinking is not autonomous or reactive, it is about concepts, reconsideration, planning and decision making. It is not about the elaboration of the information structure already existed in our brain.

Further, in HCI, "reflection" refers to the action of thinking about the information provided by computing devices, in order to capture awareness about an action and also its presumed consequences.

Distributed cognition is theory that is built up the form of a system of functional *relationships* among its elements and mechanisms. It is a system that dynamically configure itself, in order to co-ordinate the elements to achieve a functional goal. The cognitive process is distributed across people and time. Therefore, social interactions also play a relevant role, because they call for the possibility to talk with other people about experience and this help to recall memories. For example, interactive systems for behavior change, increasingly, focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action.

Other important factor of the distributed cognition, which is actually crucial to the reflection is the physical structure or the material world. Such structures, in distributed cognition theory are called *boundaries of the unit of analysis* for cognition and are the natural or artificial environments which contain objects within it (Kirsh 1995, pp. 31; Hollan et. al. 2000, pp. 175). Embodied cognition also confirms that there is a complex relation and interaction between mind's internal processes and external structures.

The value of a good design emerges here, because if spaces and objects are part of our cognitive processes, so a well-designed artifact can improve our way of thinking (J. Hollan et. al. 2000).

3. Designing Places for Reflection (Supporting reflection on an activity, in a place)

The emergence of personal computers brought computers to the new environments such as the home environment and it defined new usages for information technologies (e.g. Venkatesh 1996). This was early on envisioned by Mark Weiser at Xerox Parc, who also introducing the idea of Ubiquitous Computing (Weiser 1991). Since then many researchers have adopted his vision for designing new computer-enhanced and interactive artifacts and environments (Dalton et al., 2016). Consequently, designers have explored design of simple, intuitive and calm interactions with such computational artifacts (Weiser 1996). Some researchers have even suggested to join the areas of interaction design and architecture as to use interaction design methods and explore interactivity at the scale of architecture (e.g. Wiberg, 2015 and Dalton, et al., 2016). It helps also to fully understand the relation between interactive objects, not only in relation to humans, but also in relation to the spaces we design and inhabit.

The idea of considering the architectural settings as an active participant in the interaction is not new (e.g. Ishii and Ulmer 1997; Wiberg 2011; Dalton et. al. 2016). Either in the HCI and architectural design researches, the understanding of interrelation and interaction between humans and the space has been long the subject of study.

Further on, ways of articulating the relation between people acting in a particular space with the use of wearable objects and how such objects and tools enable us to take action in the world has been extensively explored from the viewpoint of Embodied Interaction. Embodied interaction is the phenomenological study of such interactions. It examines engaging human body and social context with materials of digital artifacts. This kind of interaction is enabled by the realization and concretization of data (Robbins et. al. 2016; Hornecker and Buur 2006; Dourish 2004).

As it has also been described in the previous section, a distributed cognitive process – an object-related reflection – can be defined as a system of functional relationships among the elements that participate in it (Hollan et. al. 2000). The elements are for instance, user, user's activity, other people, objects and also the architectural space. The particular interactions among these elements, give meaning to an architectural space, which has been also the subject of many studies. For instance, the emphasizing role of the "place" over "space" – "home" over "house" – and the way an architectural space can become meaningful, personal and characterized through its objects, people, activities, memories and etc. that inhabit within (e.g. Harrison and Dourish 1996). In addition, "Place", in humanist geographical studies is a location with a set of meanings and attachments, it is where we can find a combination of materiality, meanings and practices (Cresswell 2009; 2014). Place has been seen also as a "process", where it is produced through actions and iterations, through material continuity of people and objects that participate in time-space practices of the locale (Pred 1984, pp 280).

Therefore, in this chapter we suggest to shift the focus from the notion of "space" towards the notion of "place" for designing environments for reflection.

Considering that 1) Places, similar to objects, can evoke thoughts in user, because they hold memories and cultural meanings, they structure people's behaviors; 2) Social Internet of Things (SIoT) can augment this property of places, so we suggest to move towards using these augmented places for reflection.

Places and Situated Reflections

Reflection recalls memories, actions and experiences and supports people to understand and frame a situation (Dewey, 1938; Schön 1983; Hallnäs and Redström 2001). Reflection demands continuity, which is a process of making sense of one experience, based on the meaning derived from past experiences (Dewey, 1938). It helps to guide people to understand a situation deeply, in order to take careful and informed courses of actions for change. Nevertheless, a technologically enhanced place, in order to be of support for reflection, needs to help inhabitants to build a longish and constant process of engagement within it [15]. To this aim a place should create slow and thoughtful interactions with user instead of merely and passively representing the information.

On the other hand, people usually use and interact with objects in order to do a task. Also, according to the Activity Theory, which is a well-grounded theory in HCI and Interaction Design arena, the user forms an activity oriented relation with the artefact (ref.). Activity in this framework, is a purposeful action that is directed to accomplish a specific user's goal or need through an object. Places play also crucial roles in this activity oriented relation with objects. The place where an action is usually being done is the place where we should consider to design also for reflection on such action.

As Suchman puts, all human actions are situated – actions depend on the circumstances and the context of the activity. For *Situated Actions* she referrers to that interrelationships between actors, activity and the context (Suchman 1987; Clancey 1993).

Putting this in a simple way: For instance, if we consider designing for reflection on cooking as an activity, then the place is the kitchen. What makes a kitchen a place are the situated activities and materials that can be found only there. Cooking in this context, is situated because it is usually being done in a kitchen, which is a place with its specific materials, tools, appliances and etc.

The Embodied Interaction on the other hand, views tangibility as a key mean of interaction, but it takes a broader stance by envisioning meaningful interaction with technology inspired not only by physical objects but also social and spatial phenomena of everyday life [16].

Referring again to the distributed cognition theory, we are *spatially located creatures*. We must use directions, reconfigure objects according to the space in order to enhance our performance. The way we manage our spaces are also part of our way of thinking (Kirsh 1995). Further the environments in which people are culturally embedded, provide the space and resources for learning, thinking and problem solving (Kirsh 1995; Hutchins 1995; J. Hollan et. al. 2000).

3.2 Interactive Artifacts and Reflection

What we mean by an Interactive Artifact, is a physical, computational and human-made thing, that in involved in an interaction process – *action and influence* – with humans and other things. Sherry Turkle sees a computing artifact as such that reacts immediately to each action performed by human (1984) and as Suchman describes (Suchman 2007, pp. 38):

> *"The greater reactivity of current computers, combined with the fact that, like any machine, the computer's reactions are not random but by design, suggest the character of the computer as a purposeful and, by association, as a social object."*

There are a large number of projects that demonstrate how tangible and Smart Objects can be designed to support tasks in everyday life – stretching from simple functional tools to social, networked and connected objects that can support reflections and capture awareness about a behavior (Ploderer, et. al. 2014; Bakker et. al. 2014; Robbins et. al. 2016; Hornecker and Buur 2006). (e.g. ambient devices such as Home Joule) Therefore, we seek to take advantage of this technological phenomena and consider "reflection" as a very specific task that people need to perform in order to improve their problem-solving skills, specially, when it comes to solve complex problems (Hallnäs and Redström 2001).

According to the theory of distributed cognition, reflection as a way of thinking and problem solving is not only an individual and internal activity, but it is also social, and it does not only involve individual humans but also the objects and environments that are part of the process (Rogers 1997, Hutchins 1995). The value of a good design approach to SIoT systems emerges here, because, if materials and objects are part of our cognitive processes, then a well-designed artifact can influence and enhance our way of thinking (J. Hollan et. al. 2000).

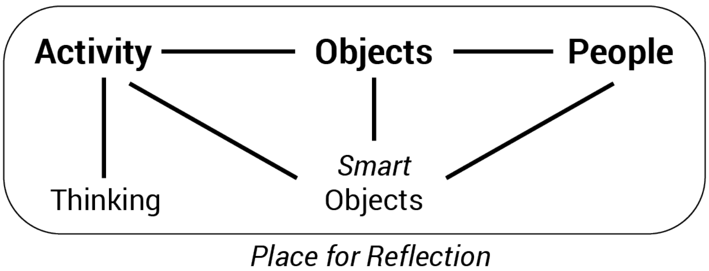

Figure 1 Elements of a place for reflection

Given that, we suggest, that if we are increasingly surrounded by computing and smart artifacts in our spaces, and if those artifacts are not only tools, but also objects that influences our thinking and behaviors, then why do not we take on one such approach to the design and development of social IoT system? If we really are going in the direction of "smart objects" we suggest that we can find a solid ground here for thinking about a design space for SIoT systems that does not solely focuses on the design of smart objects, but rather on the relations between people, objects, activities and places.

With this as our point of departure we would now like to illustrate the relations and then focus on one central element at a time. In doing so we would like to suggest to start from places, as they are physical surrounding that people, their activities and objects are usually situated within it. They prescribe to contain specific types of artifacts and specific types of social interactions according to their functions. Accordingly, there are tasks that belong to that specific space – i.e. kitchen, pans, family members, cooking. With this in place we will then illustrate other elements and relations around it (figure 2).

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4. A Design Agenda for the Social Internet of Things

The Social Internet of Things (SIoT) is a concept that combines social networking concepts with the IoT or smart devices (Azori et. al. 2012). So, if we consider to use this technology –SIoT– for supporting people's reflection, we need to take into account two main principles of it: 1) they can socialize with other smart objects and spaces so to create their own social network to exchange information and dialogue; 2) they can also help users to socialize to each other (Azori et. al. 2014). These two principles resonate well with two important components that can evoke and influence reflective thinking, which are first, having *the interaction with objects* that are meaningful and recall memories and experiences in a space. This component augments/amplifies/can be more effective, if the objects of the same experience, memory and activity are actually connected together and can provide feedbacks not only to the user but also to each other.

The second important component of reflection is the possibility to socialize and *to talk about experiences with other people*, which can be also augmented in SIoT, simply because people are connected through computers – e.g. social networks, mobile apps, etc. – with each other, so it facilitates conversations and dialogues.

Considering these points, we seek to explore the properties that make an architectural space, a "place" for reflection. We do so by reflecting and analyzing the relationships that a space makes with other elements within it.

We would now like to present three main relations between a place and: 1) Objects; 2) Activities; 3) People. Linking/Association the concept of "place" with each of these components, we call them respectfully 1) Place of the Activity; 2) Place of the Object and 3) Place of the People. Although it might seem that these relations are one to one and isolated, they are actually dynamic and each relation is actually constructed through relations with other elements as well. We suggest that there is an opportunity for reflection around these dynamic relations and interrelations, in order to design better places for reflective thinking. Referring again to the distributed cognition theory, and considering reflection as such a process, so the configuration and the relation of these elements in a place, play crucial roles (Figure 2).

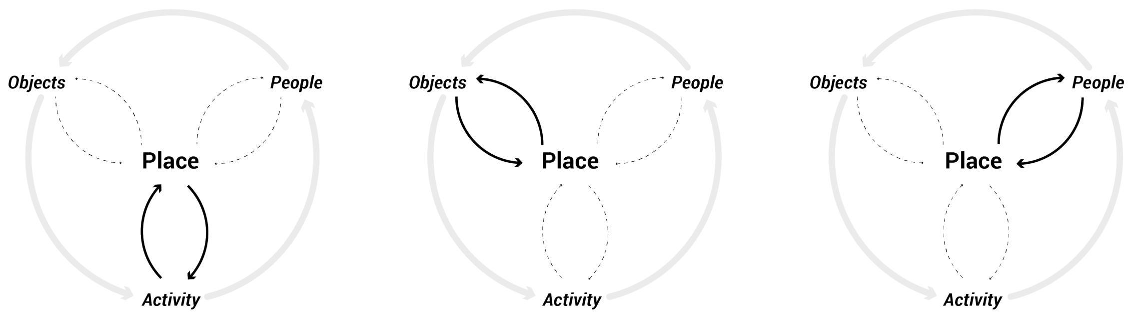

Figure 2 Relations between a "place" and other components within it

Place of the Activity:

In any given architectural space, people are usually engaged in many different activities. Most of these activities are often associated with that particular architectural and spatial setting. The relation between activities and a space, actually creates a "place" of that activity. Because the activity itself bring particular meanings, cultural expectations and definitions [4]. For example, a "classroom" is an architectural space, where students, are engaged with "learning physics" –as a specific topic of study. "Learning physics" is the main activity of students and it is related to many other different activities, such as reading, writing, talking, participating in discussions and etc. Teachers are also engaged with "teaching physics" as a main activity, related to many other tasks.

Thus, the architectural space definition and meanings are closely related with the activities that do occur in that space. Considering the "classroom" as a place for learning, accordingly, there are tasks related to that place, such as writing, being engaged in a discussion, that by definition take place in a classroom.

Place of the Object:

People engage in different activities in relation to objects, which are generally presented in a specific space. Using the same example as above, in a "classroom" for instance we find video projector, whiteboard, learning tools, papers, pens, etc.

Then we can for instance categorizing these objects according to the activity. For example, for the activity of writing we use, pen, paper, or keyboard in a classroom. Considering objects in their place, thus for designing an interactive and smart object for reflection on writing, it seems appropriate to pick an already existing object, which supports that activity and other actions related to it in the place of that activity.

Place of the People:

In a place like classroom, usually it appears to exist other tiny smaller places and corners. Those tiny places, can belong to a specific inhabitant, or to a specific group of people, or they can even belong to nobody, as a place for social interaction. For instance, when we call a specific place in classroom "my place", this actually means that place is fixed and it has been configured and shaped according to my daily activities, my things, memories and thoughts. We often spend our times and do our daily activities, within those personal places, even though we are located in bigger and social places such as a classroom. One of the characteristics of a personal place is that when other people interact with it, they may not fully recognize its whole structure, meanings and configurations. As opposite of a social place which structures and the configurations do not belong to a specific person.

(Place is a dynamic physical space which is constantly becoming a human product …)

However, and although the examples we have used here, for instance the "classroom" illustrate the relation between the place and the objects (e.g. whiteboard, papers, pens, etc) and how it might support reflective thinking we should notice that 1) there is not a deterministic relationship between the places and the tools on the one hand, and that it automatically leads to reflective thinking. Further, we should not only imagine places of functional value (e.g. as a context for problem solving), but also expand this way of thinking about the relation between places and reflections to places that support other forms of reflective thinking (e.g. a church, a temple, or a cemetery might not provide grounds for problem solving foremost, but might be places that support other important forms of reflections).

Further, we view the relation between places, tools and reflections, as enabling relations rather than thinking about these elements as standing in some form of cause-n-effect relation to each other. For sure, there can also be reflective thinking outside of these places (for instance to think about a place, but not physically being there, for instance as a source of inspiration), and we can do logical problem solving without pen and paper. However, to be in a particular environment, in a particular place might spark creative thinking, and tools might be helpful for complex reflective thinking. Further, we should also acknowledge the additional enabling dimensions that the social IoT adds to this spectrum of thinking with objects. Networked computational objects can do things for us, connect us to other people and places, and transmit data from our local setting, and our current activities to remote places, persons, representations and algorithms. As these new forms of objects also enable these new things we need a *relational approach* to design the social IoT as to have a rich understanding of how smart things not only enable something in relation to a particular person at a particular place, but how these networked objects can also completely redefine who has access to a place, what it means to participate in a particular place, and the relations between people, objects and places in processes of reflective thinking. To address such concerns we need frameworks that acknowledge relational concerns and this paper suggest one such framework for thinking about relational aspects in the design of the social IoT.

5. Conclusion

In this chapter, we have explored the relation between places, activities, objects and what has recently been labeled the "social internet of things" (social IoT). As s complement to the social IoT agenda, we have in this chapter suggested that there is a need to explore the relations between objects, places, user and user activity in order to design supportive places for reflection – where IoT objects support reflective thinking in such computer enhance places and in an increasingly networked world. We have described how we have grounded this position in established theories of human-activity-object relations, including the frameworks of distributed cognition and situated actions, and we have positioned our work in relation to the notion of embodied interaction as to further explore the relation between people and (smart) objects.

We suggest that our work can contribute to the design of better places for reflection by considering reflection as a key concept in the production of design outcomes. In addressing this aim we have defined a preliminary set of design guidelines for design of computing places that can support reflection. In this chapter, we have done so by considering the *relations* among elements in a place where objects and people are interconnected in Social IoT systems.

As to conclude this chapter we suggest 1) that a central dimension in design of places for reflection is the study and implementation of *relations* among the components within it: people, their activities, and objects, and accordingly we suggest 2) that a central theoretical contribution from our work is to further conceptualize the social IoT as not only a technical platform, but rather see the social IoT as a relational concern that enables new places for reflections – with and through objects, and together with others.

References

1. Dalton, N., Schnädelbach S., Holger, Wiberg, M. (Eds.) (2016) Architecture and interaction: human-computer interaction in time and place, Springer.
2. Nelson, H. G., Stolterman E., .2014. The design way. Cambridge: MIT press.
3. Hollan J., Hutchins E., Kirsh D. 2000. Distributed Cognition: toward a new foundation for Human-Computer Interaction Research, ACM transactions on Computer-Human Interaction 7, 2: 174-196
4. Gero J., Kannengiesser U., .2003. Function-behaviour-structure; A model of social situated agents, in IJCAI Agents Workshop.
5. Wiberg, M. (2015) Interaction Design Meets Architectural Thinking, ACM interactions, March + April 2015, p. 60-63.
6. Ashton K., .2009. That 'Internet of Things' Thing: In the real world, things matter more than ideas. RFID Journal June2009, from http://www.rfidjournal.
7. Bakker S., Hoven E., Eggen .2015. Peripheral interaction: characteristics and considerations. Personal and Ubiquitous Computing 19(1): 239-254.
8. Bellinger G., Castro D., Mills A., .2004. Data, Information, Knowledge and Wisdom, Systems Thinking, from http://www.systems-thinking.org/dikw/dikw.htm
9. Bergström, Jenny, Clark, Brendon, Frigo, Alberto, Ramia Mazé , Johan Redström, Vallgårda, Anna .2010. Becoming Materials: Material Forms And Forms Of Practice, Digital Creativity, 21,3:155-172
10. Bernd Ploderer, Wolfgang Reitberger, Harri Oinas-Kukkonen Julia Gemert-Pijnen, "Social Interaction and reflection for behavior change", Personal and Ubiquitous Computing 18, no.7 (2014), 1667-1676.
11. Cresswell T. (2009) Place. In: International Encyclopedia of Human Geography. Thrift, N. & Kitchen, R. (eds.). Oxford: Elsevier, Vol. 8: 169-177.

12. Cresswell T. (2014). Place: An Introduction. Sussex: Wiley-Blackwell Ltd.
13. Dalton, Nicholas S, Schnädelbach, Holger, Wiberg, Mikael; et al. (Eds.) (2016) Architecture and interaction: human-computer interaction in time and place, Springer.
14. Eric Baumer, Vera Khovanskaya, Mark Matthews, Lindsay Reynolds, Victoria Schwanda Sosik, Geri Gay, "Reviewing Reflection: On the Use of Reflection in Interactive System Design".2014. In Proceedings of the ACM Conference on Designing Interactive Systems (DIS'14). New York: ACM, 93–102.
15. Ghajargar M. (2017). Toward intelligent environments: Supporting reflection with smart objects in the home. ACM Interactions 24(4):60-62.
16. Hallnäs L., Redström J. 2001. Slow Technology, Designing for Reflection. Personal and Ubiquitous Computing, 5(3), 201-212.
17. Harrison S., Dourish P. (1996) Re-Place-ing Space: The Roles of Place and Space in Collaborative Systems. In the proceeding of ACM conference on Computer supported cooperative work (CSCW '96), 67-76.
18. Hollan J., Hutchins E., Kirsh D. (2000) Distributed Cognition: Towards a New Foundation for Human-Computer Interaction Research. ACM Transactions on Computer-Human Interaction 7(2): 174-196.
19. Hornecker, E., Buur, J. 2006. Getting a grip on tangible interaction: a framework on physical space and social interaction. In Proceedings of the SIGCHI conference on Human Factors in computing systems (CHI'06), 437-446.
20. Ishii, H., Ullmer, B., .1997. Tangible bits: towards seamless interfaces between people, bits and atoms. In Proceedings of the SIGCHI conference on Human factors in computing systems (CHI'97), 241.
21. Kirsh, D. (1995) The Intelligent Use of Space. Artificial Intelligence 73: 31-68.
22. Lambros Malafouris .2008. At the Potter's Wheel: An Argument for Material Agency. In The Material Agency Lambros Malafouris and Lambros Knappett (eds.). Springer US, 19-36.
23. Lambros Malafouris .2015. Metaplasticity and the Primacy of Material Engagement, Time and Mind, 8,4: 351-371.
24. Lambros Malafouris, Renfrew Colin. 2013. How Things Shape the Mind: A Theory of Material Engagement. MIT Press.
25. Mazalek, A., Hoven, E. V. D., .2009. Framing Tangible Interaction Frameworks. Artificial Intelligence for Engineering Design, Analysis and Manufacturing 3: 225-235.
26. Odom, W., Banks, R., Durrant, A., Kirk, D., Pierce, J. 2012. Slow technology: critical reflection and future directions. In Proceedings of the Designing Interactive Systems Conference (DIS '12). 816-817.
27. Paul Dourish .2004. Where the Action is. MIT Press.
28. Pred A. (1984). Place as Historically Contingent Process: Structuration and the Geography of Becoming Places. Annals of the Association of American Geographers 74(2), 279-297.
29. Robbins, H., Giaccardi, E., Karana, E. 2016. Traces as an Approach to Design for Focal Things and Practices. In Proceedings of Nordic Conference on Human-Computer Interaction (NordiCHI'16), 19.
30. Rogers Y. 1997. A Brief Introduction to the Distributed Cognition. Retrieved January 11, 2017 from: http://mcs.open.ac.uk/yr258/papers/dcog/dcog-brief-intro.pdf.
31. Rowanne Fleck .2012. "Designing for Reflection, Sustainability and Simplicity", Presented at: Workshop on Simple, Sustainable living, (CHI'12), Austin, Texas, USA.
32. Schön D., .1983. The reflective practitioner: how professionals think in action. Basic Books.
33. Shaer O., and Hornecker E., .2010. Tangible user interfaces: past, present, and future directions, Foundations and Trends in Human-Computer Interaction 3, 1,2: 1-137.

34. Suchman, L. (2007). Plans and Situated Actions: The Problem of Human–Machine Communication. New York: Cambridge University Press.

35. Taylor, A. 2015. After Interaction, Interactions XXX.

36. Venkatesh V., .1996. Computers and other interactive technologies for home. Communications of the ACM, 39:12.

37. Weiser M., .1991. The Computer for the Twenty-First Century. Scientific American, 265,3: 94–104.

38. Weiser M., Brown S., .1996. Designing Calm Technology, Xerox Parc, from http://www.ubiq.com/weiser/calmtech/calmtech.htm

39. Whittaker S., Terveen L., Nardi B., 2000. Human-Computer Interaction 15: 75-106.

40. Wiberg, M. (2015) Interaction Design Meets Architectural Thinking, ACM interactions, March + April 2015, p. 60-63.

Interaction design is increasingly about embedding interactive technologies in our built environment; architecture is increasingly about the use of interactive technologies to reimagine and dynamically repurpose our built environment. This forum focuses on this intersection of interaction and architecture. **— Mikael Wiberg, Editor**

Toward Intelligent Environments: Supporting Reflection with Smart Objects in the Home

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The growing interest in the Internet of Things and in technological, connected, and computing-enhanced spaces such as smart homes (Figure 1), intelligent environments, and responsive environments connects interaction design more and more with architecture. Everyday spaces such as home environments are increasingly filled with computing and smart objects. This trend of ubiquitous computing, as envisioned and pioneered by Mark Weiser at Xerox PARC, has since worked as a basis for designing smart environments—across people, objects, and spaces. Many researchers have further investigated how the flows and patterns of activities in a space can guide the design of interactions with smart objects [1]. In particular, the notion of *place* is used when spaces frame interactions through cultural values and behavioral expectations [2].

In designing smart homes, attention is often paid to the user experience and to the ways in which those environments can support the inhabitants' daily activities. Furthermore, many smart objects aim to not only support but also capture awareness of and evoke reflections about user activities in domestic environments. For example, reflecting about activities that require reductions in energy or water consumption, or reflecting about food consumption in order to foster behavior changes toward healthier food choices. Although the purposes in those examples may differ, they share the same principle: Reflection can help people make better choices and change behaviors.

In this regard, Lars Hallnäs and Johan Redström's *slow technology* is an approach that emphasizes the role of technology to foster moments of reflection—instead of efficiency in performance—in domestic environments [3]. More recently, the HCI community has provided many experimental and speculative examples of smart devices that can support reflection in the home.

In his seminal work *How We Think*, John Dewey describes reflection as a deep consideration of experiences and actions in order to discover connections, that is, relations between things [4]. Reflection demands time and continuity; it helps guide people to understand a situation deeply, allowing them to take careful and informed courses of action for change. Reflection as an activity is not only an individual and internal process; it also requires external stimuli: objects, other people, activities, and the environment (see, for example, [5]). Furthermore, in HCI, *reflection* refers to the action of thinking about the information provided by smart objects in order to capture awareness about an action and its consequences. Accordingly, reflection can become a valuable concept in the design of everyday smart objects embedded in place [6].

People not only think with objects, but they also often engage in an activity with an object, so *reflection about an activity* is connected to the smart object, the activity, and the place [7,8]. Consequently, designing for reflection about an activity requires consideration of the relations among those factors, which deal with the social, aesthetic, and technical interactions in a given environment [2].

Insights

→ In designing a smart space, the key element is the relation between people, activities, and smart objects. This is also relevant for designing smart objects that support reflection about an activity in such spaces.

→ Analysis of the three main relations that a smart space has with other elements is essential for designing a smart object that supports reflection about an activity.

SUPPORTING REFLECTION ABOUT AN ACTIVITY

To design effective smart objects that support reflection, we can learn from the relations among existing objects, activities, and environments. However, smart objects intended to evoke reflection about an activity are not always designed in relation to the spaces where people perform that activity. They may also not be the objects with which users interact during that activity in order to achieve a functional goal. For example, the Energy Orb is a smart object in the form of a glass ball that provides real-time data about energy consumption and energy price, enabling users to modify their energy usage. It communicates by glowing in different colors—green when the consumption and pricing are low, and red when the consumption and pricing are high. It is a calm ambient technology that requires no cognitive effort from users. At this time, the Energy Orb is not an object that is used during an activity; it does not demand any relationship with the activity and its place. Consequently, users may soon not pay much attention to it. There are many other smart objects on the market similar to the Energy Orb—for instance, Home Joule and Energy Joule—that are designed with the purpose of helping users save energy and money and also to capture awareness about their energy consumption (e.g., http://www.ambientdevices.com/).

While a few prototypes of smart objects (mostly from eco-feedback technologies) experiment with such relations in mind, many others do not. For example, we can consider two examples, both related to water consumption: an eco-feedback display [9] and Waterbot [10]. While Froehlich et al.'s eco-feedback display is not used in relation to any activity in which water is used, Arroyo et al.'s Waterbot is actually installed and connected to the faucet, which is the object with which the user interacts during an activity such as hand washing (Figure 2).

Therefore, we need to consider that evoking reflection in users about an activity is appropriate when the user is:

- actually doing that activity,
- in the place where the activity is usually being done/has been done, and
- interacting with the objects and/or people involved in that activity.

In addition, smart objects in a space that aim to support reflection need to provide guidance and be persistent, instead of merely representing information.

This analysis may have some advantage for guiding the design of meaningful forms of interaction for reflection about an activity [4]. It advises designers to first consider the activities that naturally occur in a given space and the objects and people involved in that activity, and then design smart objects that evoke reflection about that activity. Thus, for designing such smart objects, the key factor is the existing relations among the components of a space.

SPACES, SMART OBJECTS, AND USER ACTIVITIES: RELATIONS

The components of a space include objects (smart, digitally enabled, or not), people, user activities, and the architectural structure of the space itself. Considering that these components are actually interconnected and related to one another, what is the design outcome? Is it the *architectural space*, the *object* for use in a particular environment, or the *object* in use for a particular activity? Or is it the *relations* among objects, people, and activities within an environment?

Having *reflection about an activity*—which is in relation with objects, activity, people, and space [3]—as a design concept, it seems clear that we should actually design the *relations* among those components. However, in order to have a systematic approach and a clear idea about the outcome of design, we may focus on one component at time and then consider the relations around it.

For this article, I will start with the smart space, since it physically contains the other components, and then illustrate the relations within it. I will explore the three main relations, namely: 1) smart space-activity 2) smart space-objects and 3) smart space-people relations.

Smart space-activity relations. In this relation, a smart space becomes a "place" as it holds particular activities, cultural expectations, and definitions [2]. For example, "home" is a private architectural space where people live their private lives, have personal relationships, and perform activities that are often distinct from those in their public or professional lives. Thus, the architectural space definition and meaning are closely related to

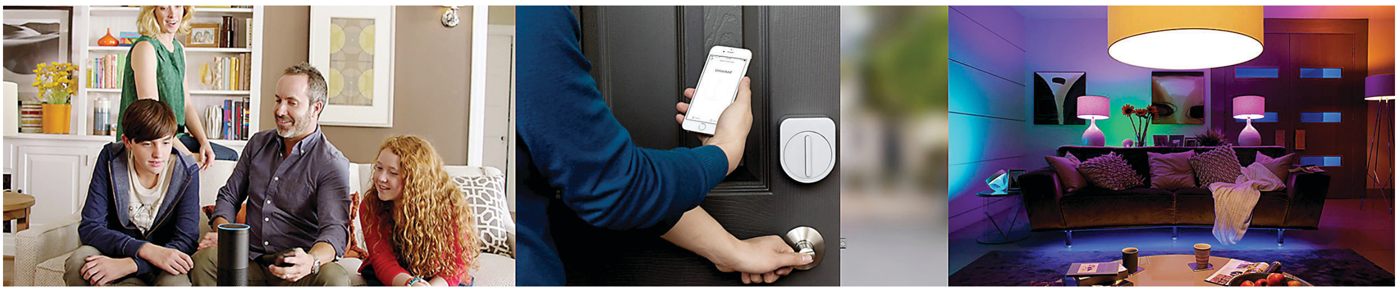

Figure 1. The smart home, from left to right: Amazon Alexa, Insitu Smart Lock, Philips Hue Smart Lighting.

TOP IMAGE COURTESY OF HOLI

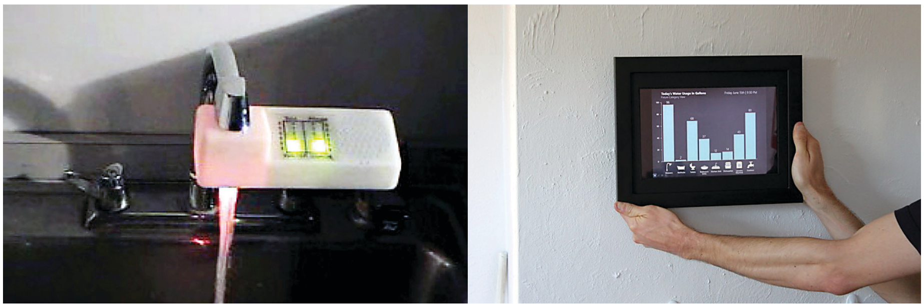

Figure 2. left: Waterbot [10] right: eco-feedback display [9].

the activities the user usually does in that space. For instance, considering the home as a smart space, a *kitchen* is defined as a place where people *make food*. Accordingly, there are tasks related to that place, such as cooking, boiling water, cutting vegetables, and so on. Those are activities that by definition occur in that specific place. Other examples are, for instance, *sleeping and waking up* in a *bedroom* or *taking a shower* in a *bathroom*. Thus, for example, in designing for *reflection about the activity* of *taking a shower*, the *bathroom* is the right place for evoking reflections about that activity.

Smart space-objects relations. According to the definition and meaning of the space, people engage in tasks in relation to objects, which are generally presented in that specific space. Considering a smart home as an example, in a kitchen we find pans and an oven; in a bedroom, we find a bed; and so on. So, for designing a smart object for reflection about the activity of sleeping, it seems appropriate to pick a preexisting object that supports that activity and other actions related to it. For example, Bonjour is a smart alarm clock that was designed to support the same user activity for which the original was invented: waking up on time. And for that reason, it is usually placed next to a bed in a bedroom (Bonjour startup: https://www.indiegogo.com/projects/bonjour-i-smart-alarm-clock-with-a-i-sleep--2#/). Bonjour is an AI conversational agent. It is connected to the weather forecast, iCal, Google calendar, Google maps, and traffic monitoring so it can adjust the wake-up time for a user if certain conditions are met. This alarm clock also supports good sleep, which is another activity naturally related to waking up on time! Thus, an alarm clock could become a smart object not only to support waking up on time and sleeping well, but also to evoke reflections on those activities for the user with the goal of improvement.

Smart space-people relations. Some places are for a specific person. For instance, when we call a specific place in our home "my room," this actually means that place has been configured accordingly to my taste, my daily activities, and my things. When other people interact with that place, they may not fully recognize its whole structure and configuration. Alternatively, there are also spaces that are designed for social interactions, for example the dining area in a home environment, which structures configurations that are not specific to one person.

In our spaces, which are increasingly computational and intelligent, we use objects in our daily activities. Through this article, I sought to build upon existing bodies of knowledge that are well grounded in architecture and HCI. They suggest that we first observe the pattern of people's activities and the objects of use in a space in order to design better and supportive architectural spaces, as well as to design better computing artifacts that can support user activities [1,8]. In this way, an architectural space becomes smart by supporting natural existing relations within it, such as relations among people, objects, activities, and the space itself. Further, considering these relations when designing smart objects to support *reflection about an activity*—instead of creating new objects and consequently new usage and interactions—is a valuable way of structuring the analysis of complex spaces [8]. This is well grounded in theories (e.g., distributed cognition) that describe how people think with objects, and that reflection is distributed across people, objects, and spaces [7,8]. There are three main relations between the architectural space and other components in it: people, activities, and objects. Analyzing those relations becomes even more relevant as we increasingly consider reflection as a goal for design outcomes, especially for the design of smart and interactive artifacts [6].

Endnotes

1. Venkatesh, V. Computers and other interactive technologies for home. *Communications of the ACM 39*, 12 (1996).
2. Harrison, S. and Dourish, P. Re-Placing space: The Roles of place and space in collaborative systems. *Proc. of the 1996 ACM conference on Computer Supported Cooperative Work*. 1996, 67–76.
3. Hallnäs, L. and Redström, J. Slow technology: Designing for reflection. *Personal and Ubiquitous Computing 5*, 3 (2001), 201–212.
4. Dewey, J. *How We Think*. D.C. Heath and Co., Boston, 1933.
5. Rogers, Y. A brief introduction to distributed cognition. 1997; http://mcs.open.ac.uk/yr258/papers/dcog/dcog-brief-intro.pdf
6. Ghajargar, M. and Wiberg, M. Thinking with interactive artifacts: Reflection as a concept in design outcomes. *Design Issues*. Forthcoming 2017.
7. Turkle, S. *Evocative Objects: Things We Think With*. The MIT Press, Cambridge, MA, 2011.
8. Whittaker, S., Terveen, L., and Nardi, B. Let's stop pushing the envelope and start addressing it: A reference task agenda for HCI. *Human-Computer Interaction 15* (2000), 75–106.
9. Froehlich, J. et al. The design and evaluation of prototype eco-feedback displays for fixture-level water usage data. *Proc. of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, New York, 2012, 2367–2376.
10. Arroyo, E., Bonanni, L., and Selker, T. Waterbot: Exploring feedback and persuasive techniques at the sink. *Proc. of the SIGCHI Conference on Human Factors in Computing Systems*. ACM, New York, 2005, 631–639.

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Designing IoT Systems that Support Reflective Thinking: A Relational Approach

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Systems are, to a large extent, about relationships between people, activities, objects, technologies and places. A systems approach focuses on how things are interrelated, and what the different parts can accomplish together. In similar terms, reflective thinking is also relational. We think together, and we are increasingly using smart objects to think with. However, designing IoT (Internet of Things) devices typically relies on artifacts rather than relationships. In this paper, we present a modeling technique for the design and analysis of IoT artifacts and systems that is fundamentally relational in its approach. We drive this relational approach from an IoT perspective, and we ground our work theoretically in terms of how a user's activities and relationships with objects are fundamentally relational. Having outlined the need for relational approaches to designing IoT systems, we first present three examples, where we demonstrate how our relational approach allows for the analysis of existing smart objects designed to function in different relationships with the user, user activity and the situation. Accordingly, we present these IoT systems from the perspectives of the "augment me", the "comply with me", and the "engage me" relational models. Having presented these three examples that illustrate how IoT systems can be analyzed as systems of relationships, we then present the prototype of an IoT artifact intended to support reflection in user. With this fourth example, we introduce the "make me think" relationship, and also show how our modeling technique can be useful for design of new IoT systems.

Accordingly, we suggest a modeling technique that can be used as a tool for designing and analyzing IoT systems. We believe this modeling technique can contribute to a relational approach to IoT. We conclude this paper suggesting that our proposed modeling technique cannot only help to model relationships between a user and a smart object but can also be scaled, allowing for the modeling of more complex IoT systems, where there are an increased number of users using many smart objects in different places, but still integrated as a complex system.

Keywords – IoT System, Design, Modeling, Reflection, Relationships, Smart Object.

Relevance to Design Practice – This paper offers a relational approach to the modeling of IoT systems. This approach allows for the analysis of the relationships between the components that constitute IoT systems. In doing so, we suggest a modeling technique in order to support both the analysis and design of IoT systems. This could be as a support for either industrial and interaction designers, not only for shaping a particular kind of relationship, but also for designing physical artifacts that can support that kind of relationship.

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Introduction

It has been predicted by many scholars that we will be increasingly surrounded by autonomous, computational, and interactive artifacts (e.g. Zuboff 1984; Weiser 1991; #Author 2017). Not only do these smart objects increasingly surround us, but we also experience different relationships with different devices, and in relation to different interactive systems. For instance, we *use* a calculator as a *tool* to carry out mathematics, we *blend with* step counters to *motivate* us to take more steps, and we *install* a smart thermostat and *let it* regulate the temperature in our homes. In short, we have different *relationships* with different smart, computer-based artifacts. Each relationship suggests not only how we will interact with an artifact, but also what it can do for us, and how different things serve different purposes that, when taken together, make our lives easier. Some have referred to this trend in terms of the emergence of *artifact ecologies* or *the new ecology of things* (e.g. Allen 2007; Jenkins 2015; Robbins, Giaccardi and Karana 2016), *interaction landscapes* (Wiberg & Zaslavsky 2010; Wiberg 2012), or simply *interactive systems* and *interactivity fields* (Janlert and Stolterman 2017).

The modeling of these different ways through which we relate to these systems of smart things is the main focus of this article. We suggest using these models not only as a generative tool aiding the design of such artifacts, but also as an analytical tool to study existing ones. Although it has been often acknowledged that an IoT device works in a system of things, places and people, the design of such systems often followed a traditional approach, wherein the single device is considered the final product (e.g. Hornecker and Buur 2006; Kortuem, et. al. 2010).

However, while this traditional product design approach allows a focus on the properties and the overall functionality of a single artifact, it is limited for the design of bigger, interconnected and more complex interactive systems. The system approach, on the other hand, could become too complex, broad and hard to manage, meaning the outcome of design process remains undefined and continuous. As a contribution to this challenge, we propose a *relational approach* to the design and analysis of IoT artifacts and systems. Although this approach aims at designing a concrete artifact as the outcome of design process, it takes a broader stance by defining artifacts' functionalities, behaviors and forms, based on a particular relationship. In this regard, the relationship becomes the purpose and also the intention of designing the artifact.

The interest in designing for reflective thinking in the human-computer interaction (HCI) and design communities is growing, especially with the purpose of behavior changes in user. However, there are few examples in literature that describe attempts to create guidelines and theories for the design of such systems. Fleck and Fitzpatrick, for instance, provided a framework summarizing the literature outside of the HCI field about reflection. They included in their framework three important aspects of reflection, namely purpose, condition and levels of reflection and then they listed technologies that could support reflection (Fleck 2012; Fleck and Fitzpatrick 2010). In a more specific way, Baumer et al. (2014) saw reflection as an alternative to traditional and persuasive ways of behavior change, especially for sustainable behaviors.

As a contribution to this challenge, we suggest considering *reflective thinking* (reflection) as a user activity and reference task (Whittaker, Terveen and Nardi 2000). We believe it can help build a common ground for projects focusing on designing IoT artifacts that support reflection for a variety of purposes. Despite, in this paper, particularly the purpose for reflection is behavior change in the area of sustainable urban mobility behaviors.

Reflective Thinking

Reflective thinking as a distributed cognitive process is not only individual, but also relies on external stimuli and activities, such as materials, situations, talking with other people and writing (e.g. Papert 1980; Schön 1983; 1992; Salomon 1993; Norman 1993; Rogers 1997; Hutchins 1999; Turkle 2011). Of those external stimuli, physical objects and especially computing artifacts play a crucial role (Papert 1980). John Dewey, in his seminal work "How We Think", described how reflection is a deep consideration of experiences and actions, in order to discover connections – i.e. relationships (Dewey 1910; 1933). He further pointed out that experiences are consequences of interactions between oneself and others – people, artificial and the natural worlds. Reflection is a systematic, rigorous and disciplined way of thinking. It is a meaning-making process through which people move from one experience to the next with a deeper understanding of its relationships and connections. Reflection does not involve simply a sequence of ideas, but a consequence of ideas as Dewey stated: "… is a consecutive ordering in such a way that each determines the next as its proper outcome, while each in turn leans back on its predecessors." (Dewey 1910; 1933).

Later thoughts grow out of, and support, the earlier ones. This chain or thread of thoughts is not only an individual process, but it also involves other entities, such as other people, objects, activities and places. These entities are the components of the system and are connected to each other through relationships.

In addition, Rodgers outlines: "Reflection needs attitudes that value the personal and intellectual growth of oneself and of others." (Rodgers 2002). Furthermore, in cognitive science, it has been defined both as a top-down and also conceptually driven cognitive process. It means, reflective thinking relies on either external stimuli and internal beliefs and concepts (Norman 1993).

In short, we are interested in systems of smart and interconnected objects and how such systems support reflective thinking through relationships. Furthermore, if reflection is relational, and if we set out to design smart artifacts that support reflection, we need a modeling technique that enables us to study those relationships. One that goes beyond the study of "interaction" between computing artifacts and people and considers, instead, the "relationships" as the purpose for design. In this endeavor, we are inspired by Alex Taylor's After Interaction, in which he stated that interaction as a concept contributes to separation rather than connections and relationships (Taylor 2015). Since the concept of interaction deliberately makes a clear division between people, computing artifacts and environments, it cannot be suitable for studying the systems of computing artifacts such as the Internet of Things.

We need an approach to view computing artifacts in relation to their user, to their physical and cultural context and not as stand-alone products, focusing on the purpose of that relationship. This paper is an attempt to contribute to one such approach.

Our proposed modeling technique seeks to open up the analysis of existing IoT systems as well as supporting the modeling of new ones. To this end, we examine the relationships for three examples of computing artifact categories and create a model for each. For each model, we consider the relationships between the user, the artifact, the situation and the user's activity. Hence, we provide examples of those relationships, namely: 1) ***augment me***; 2) ***comply with me*** and 3) ***engage me***. As we will illustrate with the models, these three examples demonstrate a range of different relationships with computing and smart artifacts, which are essential to learn from in order to model the fourth model capturing the ***make me think*** relationship. Accordingly, we explore, reflection on an activity as a user task and how smart artifacts in an IoT system can support it. We model the ***make me think*** relationship by analyzing a prototype and its characteristics from an early demonstration of our concept (Lim, Stolterman and Tenenberg 2008).

We will describe in this paper how interactive artifacts enable different relationships for augmentation, compliance, engagement and reflection. We suggest that prior to thinking about designing systems of IoT artifacts, we need first to understand how to design *different relationships,* as systems are, to a large extent, about relationships or forces that connect the parts and make sense of a system as a whole (e.g. Bertalanffy 1968; Churchman 1971; Banathy 1996).

We examine reflection as a reference task, reflect on our own methodology and technique of modeling through analysis of the prototype, then conclude the paper with implications for interaction design theory and practice.

Modeling IoT Systems: A Relational Approach[i]

We create relationships with artifacts by sensing and using them during activities (Bødker 1989; Vardouli 2015). Furthermore, as Turkle (2011) suggested, we need to move beyond considering artifacts as just useful or aesthetic, and also try to consider them as companions to our emotional lives or as thought-provoking devices. Seeing artifacts as just being useful originates from using computers in the work environment and from when the notions of "interface" and, consequently, "interaction" were introduced (Norman 1988; Bødker 1991; #Author 2016). The artifacts relate also to their surroundings and with human activity. For instance, as Bødker (1989; 1991) stated, a computing artifact – a user interface – cannot be seen independently of its use, and an artifact is actually defined by its user and the nature of the activity. These relationships are influenced by not only social, cultural and environmental conditions, but also by the artifact's features itself. Indeed, the artifact's physical characteristics seem to be crucial in shaping and influencing user activity and behavior. This has been long debated in the behavior change design arena, for example Lockton's Design with Intent (2008), or the concept of artifacts's affordances that can shape and guide the way an artifact can be used (Norman 1988; 2013)

The application of the Activity Theory framework in Interaction Design also suggests that the user forms an activity-oriented relationship with the artifact (Kaptelinin and Nardi 2006). Activity in this framework is a purposeful action towards accomplishing a specific user's functional goal by using an artifact. Furthermore, the reference task agenda suggests there should be a focus on a specific user task and an investigation into the ways the computing artifact can support that task (Whittaker, Terveen and Nardi 2000). Therefore, for the design of IoT artifacts and systems, a key factor is to understand these activity-oriented relationships.

For the design community, this is not new: design has always been about manifesting and guiding such relationships in artifacts. Interaction design, for instance, is about the design of various computing artifacts which do not appear as an isolated artifact but interact with users and the environment, accordingly making different relationships between them (Preece et al. 2002; Verplank 2009; Dix 2009). In addition, in the HCI domain, those relationships have been suggested to be designed purposefully to support a very specific user task or activity (Whittaker, Terveen and Nardi 2000; Kaptelinin and Nardi 2006). On the other hand, in a traditional Industrial Design process, a user's activity to achieve a functional goal has been a crucial factor in defining the artifact's functions, forms and behaviors. Therefore, the user's activity, the use, the artifact's characteristics, and aesthetic and cultural values, all determine the relationship between the user and the artifact (e.g. # Author 1997; Gero 2003; Crilly 2008).

With physical artifacts, the physical and sensory properties – e.g. forms, colors and texture – influence the user's activity during interaction, whereas with digital artifacts – e.g. websites and mobile apps – the representation of the information on the user interface plays the most important role (e.g. Norman 2013). Hence, artifacts can shape our mind, influence our behavior, activity, and our way of thinking (Malafouris 2013; Turkle 2011; Salomon 1993). Accordingly, we believe we need a better understanding of such relationships in order to design better systems that support reflection. To this end, we first explore three different relationships, then determine the properties of the ***make me think*** relationship from analysis of a prototype to produce a model.

So, we will first present three examples of relationships with computing artifacts and how they can be related to a user's task, goal and the situation. We will do this in order to lay the groundwork for: 1) introducing the model of ***make me think***, 2) presenting the properties of the computing artifact able to evoke reflection, considering different interactions with the user, other artifacts and the environment.

Understanding The "Augment Me" Relationship

One of the oldest relationships that users have formed with computers is the one that we refer to as the *augment me* relationship. In this kind of relationship, the user and the computing artifact exist in an equal and balanced collaboration. This relationship requires input from the user with the computer providing outputs in the form of perceptible feedbacks. These flows of inputs and outputs assist the user in achieving a functional goal. For instance, the early computers were simple calculators, designed to augment their user's capabilities to solve mathematical problems faster, and in a more efficient way. In this relationship, the user provides the problem in the form of inputs to the computer, which consequently completes the task of solving a mathematic problem, and provides outputs as solutions. Considering that users need to have at least some basic knowledge about mathematical operations – i.e. multiplying, addition, subtraction etc.– in order to carry out the task with a calculator, it is not just the computer that does the work, it is the result of a balanced collaboration with the user. Another important characteristic of this relationship is that the user has overall control, because the calculator provides a very narrow range of control and operations (# Janlert and Stolterman 2017).

Thus, in summary, the most important characteristics of the ***augment me*** relationship are 1) balanced collaboration between user and the artifact, 2) there is always a specific task to be undertaken in relation to the artifact, and 3) the user has overall control of this relationship – a calculator is usable only when a user turns it on, or in the case of software calculators, when a user opens the application or program. The user knows exactly when a calculator is working or when it is on, and for what particular task it will be used.

As is illustrated in Figure 1, ***augment me*** is a direct relationship between a user and an artifact – the dotted line shows the boundary and actors involved in the relationship. So, first the user and the artifact make this relationship (1.) and then the task is completed (2.), as a result of this relationship.

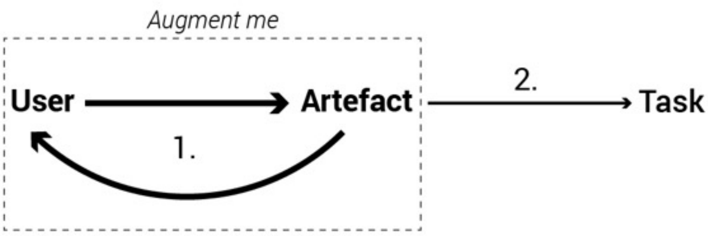

Figure 1: *Augment me* relationship model. (The numbers show how this relationship unfolds.)

This is a simple, unequivocal and direct relationship between a user and the computing artifact, which consequently creates a one-to-one conversation between actors. The actors of this relationship, their intentions and the task are substantially, and in a transparent way, known to either participant.

If one considers a different situation in which the user and the artifact are not in an equal and collaborative relationship, where they do not actually create a one-to-one conversation with each other in order to carry out a task, and where the artifact is not just controlled by the user but also by other sources of inputs/information to which it is connected, how can we then call this a relationship? This situation is the one we actually face when we seek to understand the nature of the relationship between an IoT artifact and the user. So, if we consider a computing, smart connected artifact, which has multiple sources of inputs other than just user inputs – such as an IoT device, which is an artifact that can receive/send data from/to multiple parties – is there any real relationship between user and artifact? How can we describe and interpret it?

Understanding The "Comply with Me" Relationship

When computers became faster, ubiquitous, artificially intelligent and also connected to the Internet, they became capable of carrying out more complex tasks, some autonomously. In other words, users were no longer required to participate in some tasks, and could let the computer do the task for them. This could lead to a new kind of relationship between users and computing artifacts, the ***comply with me*** relationship. In this relationship, the user undertakes a few simple steps prior to running the artifact, such as adjusting and installing the device, and then the device itself carries out the task for the user. In this context, the relationship is focused mostly on the computing artifact and the situation, which includes all the different information and input sources, such as other smart artifacts, both local and remote. Therefore, as we can see, there is no actual and direct relationship with the user in order to carry out a task. The relationship between user and the artifact is formed around the way in which the artifact provides feedback through showing the status of the system. The types of feedback provided to the user can vary. They can be in the form of sound notifications, text messages or graphical representations, which aim to provide real-time information about the status of the system or alert (e.g. the nest thermostat displays the texts: learning, cooling, away or gives graphical representations such as the green leaf when a user is saving energy).

For instance, the relationship between the user and the nest™ thermostat is a ***comply with me*** relationship. The nest is a smart thermostat, connected to the Internet. Its embedded sensors and algorithms learn the user's central heating usage and it will adjust itself automatically in order to maintain the user's thermal comfort. It is also connected to cloud services, receiving real-time data from different sources, for instance from local weather channels, in order to adjust the indoor temperature in relation to the outdoor temperature. It can also be remotely controlled using a mobile app. As a result of these relationships between the nest and the situation – other elements and artifacts that nest is connected to through Internet connectivity– nest is able to satisfy its user comforts. In this context, adjusting the temperature, for example, is the task and maintaining thermal comfort is the purpose of that task. This kind of relationship differs from the ***augment me*** one in the way the user is involved in the task. In ***comply with me***, user let the artifact do the task, there is not an actual balanced collaboration between the user and the artifact nor a direct conversation between them, the artifact complies with its user. To do so, for instance, nest is in conversation with many other sources of input, a scenario we refer to as situation (Figure 2). nest does not require any human intervention to carry out the task and it is almost invisible, working silently in the background, and requiring very little cognitive effort by its user.

In contrast to the nest, which is designed to do a very specific task – adjusting the temperature – Amazon Alexa is another example that forms a ***comply with me*** relationship, but is able to carry out multiple tasks for its user. The Amazon Alexa is a home-based artificial intelligence, a conversational agent, without any particular user interface or surface with which a user may interact (Janlert and Stolterman 2014). Hence, it seems that it has been designed without one particular task in mind but for a series of tasks.

The ***comply with me*** relationship is shown in the Figure 2. The artifact first connects to the situation, which includes the whole system of other actors and information sources connected to each other. Consequently, the artifact does the task or tasks and then sends the status information to the user.

To summarize, there appears to be three relevant characteristics of the ***comply with me*** relationship. The first is the absence of a balanced collaboration between user and the artifact in order to carry out a task. The user usually acts as someone who gives orders without sufficient knowledge about the ways a task can be achieved, and the artifact is the thing that complies and carries out the task for the user, receiving information from the situation. Second, depending on the designer's intentions and the artifact's functionality, it could be one or many tasks that the artifact can undertake, complying with the user. Third, the user may not have complete control of this relationship, since this is not a one-to-one conversation, so the user is not the only actor that provides inputs in the form of information. As is illustrated in Figure 2, in the ***comply with me*** relationship, an artifact primarily relates to the situation and so its relationship with the user is secondary. The dotted line shows the underlying components involved in the relationship. So, in this relationship, first the artifact connects to the situation, which comprises the environment and also other smart objects (1.), and then the task is completed and it provides textual, aural or visual feedbacks for the user (2.).

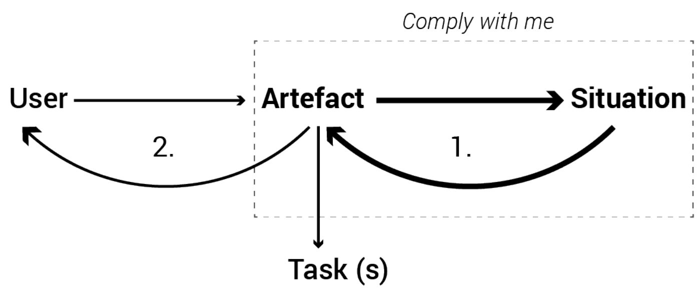

Figure 2: *Comply with me* relationship model. (The numbers show how this relationship unfolds.)

What about wearable technologies? They are designed to be put on, always connected and in touch with the user's body, and are free of any specific physical context. What kind of relationships can they create with their user?

Understanding The "Engage Me" Relationship

Wearable technology has led to having small connected computers everywhere all the time. They are usually designed in a way that can be easily worn and be in touch with our bodies. They can collect, analyze and recall data when needed. Personal data are collected by such devices using built-in sensors and Internet connectivity. The information can then be recalled and used to inform users about their actions and activities. The act of being informed about aspects of personal life (e.g. moods, performance, food consumption etc.) through self-tracking technology has been termed the quantified self, lifelogging or personal informatics (e.g. Braber 2016; Li, Day and Forlizzi 2011; Pousman and Stasko 2006). This process of collecting and storing data and then building knowledge from it, in order to provide feedback to users, has been proved to make users reflect on their actions and personal aspects of their lives. Feedback is provided through a user interface (UI) and, in almost all cases, through videos, photos or data visualizations techniques on screens (e.g. Gašević et al. 2014; Kefalidou et al. 2014; Young et al. 2015; Houben et al. 2016).

The relationship here between user, user's data and user's personal goal is what we call an ***engage me*** relationship (Figure 3). This is the most complex relationship in comparison to the previous ones because it involves the three components of the relationship simultaneously, so the user, the user's personal data and the user's personal goal. For instance, Fitbit is a wearable, is a smart bracelet and an activity tracker that tracks user activities, collects data and then provides feedback about, for instance, how many steps have been taken, how many calories have been burned, the user's heart rate and so on. It also supports and motivates users to achieve their predefined goals (Purta et al. 2016). In this kind of relationship, a personal goal is the user's motivation to undertake a task but it can also change the task – i.e. running faster or slower – as the artifact is engaged by the user and also engages the user when carrying out that activity.

Thus, the ***engage me*** relationship has the following fundamental characteristics: 1) the primary relationship is between a user, user's data and her/his personal goal, 2) the artifact is not actually used in order to carry out the task – a bracelet is not used by user in order to run– 3) the artifact is used when carrying out the task, 4) there is no specific place or time for using the artifact.

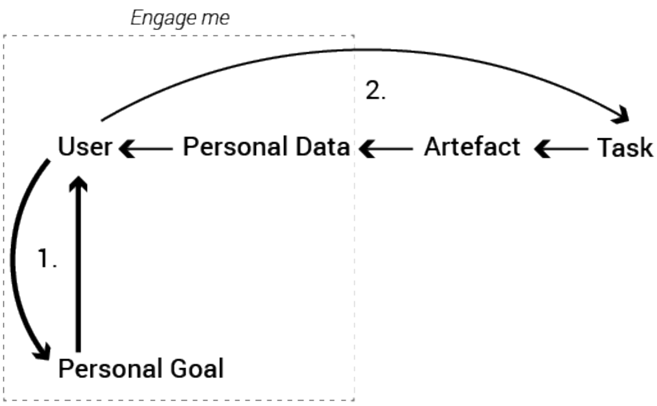

Figure 3: *Engage me* relationship model. (The numbers show how this relationship unfolds.)

These models are basic and simple, with few essential components, but we believe, we can analyze more complex IoT systems, with more users and artifacts using the same modeling technique (Brown, Bødker and Höök 2017).

So, given the analysis of models regarding the way a computing artifact relates to the user and to other components of the system, we can now think about the relationships that the user creates with an IoT system in order to support reflection as a very specific but relational task.

Designing IoT System for Reflection: "Make Me think" Relationship

The idea of using computing artifacts as tools for enhancing the learning process, creativity and especially for aiding reflective thinking is not new. In particular, designing the features of a computing and interactive artifact in a way that can foster thinking and cognitive development has been the subject of much research in the fields of cognitive and learning science. For instance, Pea's concept of "cognitive technology" is one of the early examples of concepts for designing such artifacts (Pea 1985). This concept involves using computing technology as: "mediums [tools] that help transcend the limitation of mind, such as memory, in activities of thinking, learning and problem solving". (Pea 1985) Cognitive or mind tools promote learning and thinking *with,* instead of *through,* computers, enabling learning *with* interactive technology as an intellectual and active partner. They are designed and adapted to the learner's environment in order to engage deep reflective thinking and a higher order of critical and meaningful learning. This engagement also helps learners to generate ideas in the context of problem solving (Lajoie and Derry 1993; Jonassen and Reeves 1996).

To summarize, it has been suggested that various interactive technologies seem to be effective in learning and thinking, either *through* and/or *with* them. In this regard, learning *with* interactive technologies or cognitive tool approaches are the focus of more research than ever before. Beaumie and Reeves (2007) built on Salomon's concepts of distributed cognition (1991;1993) and argued: "… the learner, tool, and activity form a joint learning system, and the expertise in the world should be reflected not only in the tool but also in the learning activity within which learners make use of the tool." Thus, as stated in the above quote, the learner or the user, the computing artifact and the activity or task are components of the learning system, forming a system of relationships as discussed in the earlier sections of this paper.

Considering the concepts of cognitive tools, and according to the theory of distributed cognition, the way cognition is distributed is first determined by the intentions of its designer. After that, it is determined by the tool's characteristics, for instance by tool affordances, forms and behaviors (Shackel 1984). Hence, a cognitive or mind tool is essentially an artifact that should be designed in a way that accomplishes their purpose and communicates the designer's intentions (e.g. Crilly 2010). In this regard, supporting reflective thinking is the purpose of the design and also the designer's intention. So, as with any other physical artifacts, it needs to be designed in order to function, thus it requires particular characteristics that enables that function – supporting cognitive activity and reflective thinking in its user. (Ghajargar, De Marco and Montagna 2017)

Before going through the analysis and defining the ***make me think*** relationship, we will provide a brief section about related works, which have been undertaken in the HCI domain.

Related Works: Designing for Reflective Thinking In HCI

The interest in designing computing artifacts to support reflection, especially in the context of everyday lives, has been growing in the field of Human-Computer Interaction (HCI) since so-called 'smart' devices have been able to collect data and communicate with the user.

In the HCI field, "reflection" refers to the action of thinking about the information provided by computing artifacts, in order to capture awareness about actions and experiences and also consequences (Sas and Dix 2009; Baumer et al. 2014). The topic of reflection has been investigated from both a theoretical and a practical perspective in the HCI field. From a theoretical perspective, Fleck and Fitzpatrick, for instance, provided a framework summarizing the literature outside of the HCI field about reflection. They included in their framework three important aspects of reflection, namely purpose, condition and levels of reflection and then they listed technologies that could support reflection (Fleck 2012; Fleck and Fitzpatrick 2010). In a more specific way, Baumer et al. (2014) saw reflection as an alternative to traditional and persuasive ways of behavior change, especially for sustainable behaviors.

Mols, Hoven and Eggen's "Technologies for Everyday Life Reflection", which suggests a more holistic design space for reflection. Based on a literature study on tools and methods for reflection, they suggest three roles that systems can take in order to evoke reflection, dialogue-driven, data-driven and expression-driven reflection (Mols, Hoven and Eggen 2016).

A focus on the materiality of interaction with physical smart objects and how it can influence human behaviors and evoke reflection has also been the subject of study in the HCI field and design (Ghajargar and Wiberg 2018; Wiberg 2018).

From a digital artifacts perspective, Kalnikaite and Whittaker (2011) developed *MemoryLane*, a digital memory application that helps people to organize their digital mementos* according to the place, people and objects. *Echo* (Isaacs et al. 2013) is an android mobile application that helps users to reflect on their daily activities, with the purpose of increasing their well-being. *Echo* seeks to go beyond just being a tool to remember events with, by having a section for reflection on past events. It records events by not only including a brief description of the event, but also the degree of one's happiness and allows for the inclusion of photos and videos.

There have also been many experiments carried out from the physical artifacts' perspective. For instance, *Data Souvenirs,* by Aipperspach et al. (2010), is inspired by environmental psychology and emphasizes the important role of the physicality and familiarity of objects that support reflection. *Lover's box,* by Thieme et al. (2011), is another example of such a physical, everyday artifact, and aims to evoke reflection on romantic relationships between couples.

Bowen and Petrelli (2011) used the concept of autobiographical memories and digital mementos as tools to help people reflect on their experiences in the home. In particular, *critical artifacts*, products of a critical design process, were used in a design study in order to enable users to envision ways of using technology in the context of personal experiences.

Considering reflection as a driver of behavioral change, a number of projects have investigated the role of physical artifacts in achieving such change. For instance, *Keymoment* (Laschke et al. 2015) is a key hook with the purpose of fostering more healthy and sustainable urban mobility behavior, by encouraging its users to take their bike key instead of their car key. In particular, the design of the key hook helps users to remember and reflect on the choice of transportation in a pleasant way, at the moment of leaving home. A similar idea of using a key hook as an artifact for reflection on urban mobility behavior has been conceptualized by Ghajargar et. al (2015), which has been inspired from environmental psychology and the theory of our implicit connection with nature (Schultz et al 2004). Mckinnon's *Domestic Reflections, Electric Reflections* (2016) which focuses on the everyday mundanity and critical design as an approach for designing interactive and every-day objects for sustainable behavior change. The *Eco-Feedback Technology* is another concept, using digital and physical artifacts, mostly ambient displays to capture awareness about user behaviors (Froehlich, Fidlater and Landay, 2010). Feng Gao's Design for Reflection on Health Behavior Change (2012), takes an instance on alternative ways to persuasion-based systems for behavior change specially in dietary context.

Reveal-it is another example of using large digital displays for empowering people, by evoking thoughts on energy consumption at both individual and collective levels (Valkanova et al. 2013). Social interactions also seem to play a relevant role in the reflection process, because they require talking with other people about the experiences, helping to recall memories. For example, interactive systems for behavior change increasingly focus on multiple users, often to encourage open-ended reflection rather than prescribing a particular course of action (Ploderer et al. 2014). Reno and Poole's *It Matters If My Friends Stop Smoking* (2016) which also focus on the role of social support for behavior change.

What Tools for Reflection Are

Reflection as a cognitive process is influenced by either internal and individual, or external and collective, components. It is a way of problem solving in relation to an individual and internal activity, but is also about the relationships with artifacts, activities, places and people (Salomon 1993; Hutchins 1999). On the other hand, an artifact that can promote reflection can also become a medium for creating such relationships between a user and their daily activities. Therefore, it seems crucial to understand the relationships between a tool for reflection and other elements in the system (Salomon 1993; Hutchins 1999). Elements include the user, who uses and interacts with the artifact, and the artifact itself, which is the tool that makes the user think and reflect about an activity – that is, an activity required to achieve a functional goal. The tool can sense, collect and process data and provide feedback to the user. Other elements include the social environment, which determines and influences the way a user interacts with the tool and carries out the activity, the physical environment, which is the physical and spatial surroundings within which the user interacts with the computing artifact and carries out the activity, the activity that users undertake in order to accomplish a functional goal, and other artifacts – physical and digital – with which the tool is connected, physically or through Internet connectivity.

In an attempt to understand what a tool for reflection in everyday use might look like, informing from vast body of knowledge in HCI about reflection, we developed a prototype of a lamp, which has some similarities, but also differences comparing to ambient devices or eco-technologies. It is similar to an ambient device, because it is a lamp, it informs the user by providing visual light-based feedbacks. However, the design of our prototype differs from an ambient device, mainly in two ways: 1) this lamp is made of modular units and the user can touch and build it physically. This would encourage the user to participate and be an active part of the light behavior, which reflects his/her behaviors. The lamp structure can also grow by adding extra units on top of it, which emphasizes even more on the design sensibility towards user's participation in building his/her own behavior; 2) changes in light behaviors that occur according to changes in user's habits, are designed in a way that show improvements and the quality. The light colors are natural white, and they do not change colors –e.g. red or green, the common light colors used in ambient devices– they just change the position from bottom of the lamp to the top and vice versa.

These characteristics and behaviors are also required in order to create the ***make me think*** relationship with the user (Ghajargar et. al 2017). Throughout this experiment – building the prototype, and defining its characteristics and behaviors – we sought to understand and demonstrate the ***make me think*** relationship model.

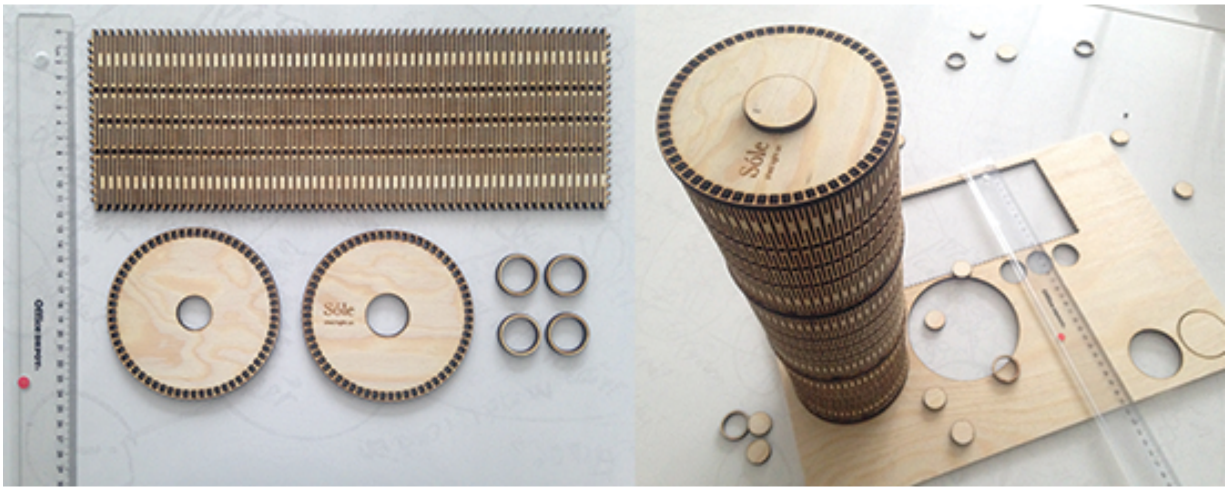

Figure 4: Prototyping the lamp

The lamp prototype initially consists of three modular lighting units. It is able to receive data from a mobile application that collected data about user's urban mobility behaviors[ii] – frequency and the choice of one means of transport over another. Then, units of the lamp lit from dim to bright, and from bottom to the top of the lamp in order to show the improvements in user's sustainable urban mobility behaviors. The lamp interacts in different ways with other components of the system, namely: 1) with the user, who primarily interacts with the artifact for the purpose of understanding and reflecting on urban mobility behaviors, 2) with the social environment and the user, which is the relationship enabled between the artifact and its context, through its presence and appearance, and 3) with other artifacts and contexts, which were, for example, the mobile app and the two contexts of indoor, which is the home environment and outdoor, from which data were received.

First, we define the characteristics according to the three different kinds of interactions. Then we will analyze the lamp's behavior and structures in order to describe the model of the ***make me think*** relationship.

Interaction with The User: The User's Engagement and The Tool's Transformation

Physically being engaged and learning with tangible computing artifacts as active partners can enhance learning and cognitive development (e.g. Price et al. 2003; Rogers and Muller 2006). In fact, arguably, this is one of the most important characteristics of a cognitive tool to be suggested since the development of the constructivism theory of learning and cognitive technologies (Piaget 1947; Jonassen 1997). A user interacts with an artifact, then the artifact provides feedback, creating loops of actions and feedback that can shape and personalize the interaction (Dietrich and Laerhoven 2014; 2016). One opportunity to incorporate this property into the physical structure of the artifact is to build it out of physically modular units that also contain information i.e. similar to Lego blocks. The modularity of the structure helps the user to be engaged more with the artifact and experiment with it, which is another important aspect of the learning process.

Accordingly, the lamp's physical structure has been designed in such a way as to provide some of those possibilities for engagement. It has been built of three unique modular units, so the user builds the lamp by physically manipulating and inserting the units. The structure also provides the opportunity to add more units to carry the light from bottom to top units (Figure 5).

As has been mentioned before, these properties are linked to the tangible and physical structure of the artifact. Therefore, they relate to behaviors, materials and shapes and so are visible to the user. Other important drivers of reflection, such as openness to interpretation, experimentation and exploration, are also supported by this level of interaction.

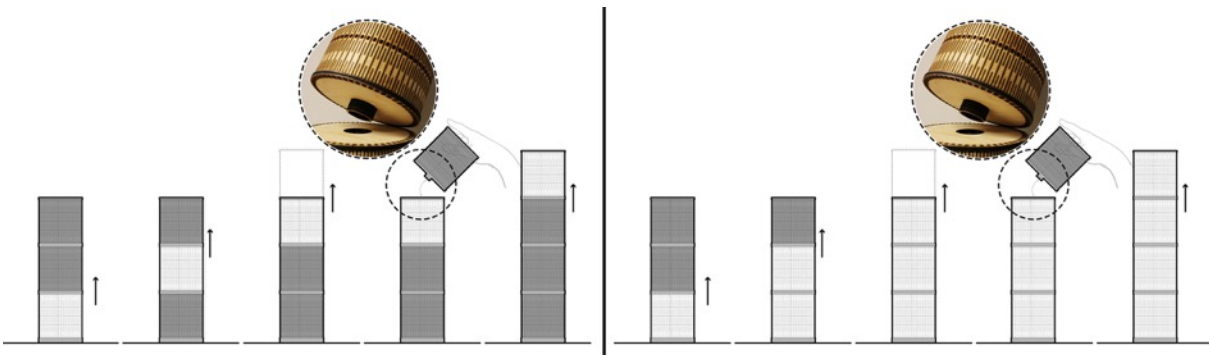

Figure 5: The lamp's modular units and its transformation.

Interaction with The Environment and The User: Communication

Reflection is a process of making sense of one's experience, based on the meaning derived and communicated from past experiences (Dewey 1910; 1933). Building on a combination of two types of communication, namely that across time and space, this level of interaction turns the artifact's transformation and feedback into a "text" (Shannon 1948; Crilly 2008). Although the "text" remains open to interpretation in the context of use, it is still clear enough to convey the message. For instance, the lamp carries information to the user – regarding their mobility behavior – by raising the position of the light alongside the structure.

Such feedback and its transformation is also defined as the carrier of information or the carrier of meaning in terms of embodied interaction (Dourish 2004). The lighting behavior seeks to convey a simple message and meaning regarding the user's mobility behavior. In this prototype, we have designed two types of lighting behaviors: A) *to arise* mode and B) *to accumulate* mode (Figure 6). Both of these behaviors show to the user, whether she/he is progressing in sustainable urban mobility behavior. This message will be communicated through A) turn off light bulbs in lower units and turn on them in the upper units, which result in raising the position of light alongside of the lamp or B) turn on more light bulbs, which results in having increased number of light bulbs which are turned on (Figure 6). The user will have the possibility to choose a light behavior between these two options.

Figure 6: Two different types of light behaviors: A) to accumulate mode B) to arise mode.

The lamp communicates this message with the user in an abstract, somehow qualitative way. It is also calm and requires little user's attention (Weiser 2009; Bakker and Eggen 2015). However, the numerical values are always accessible through the mobile application that collects data.

This is an alternative way of communication compared to the traditional ambient displays and eco-feedback technologies (changing in color from red to green), even though both share some principles. For example, eco-feedback uses also smart technologies to develop devices for the home environment to provide feedback on individual or group behaviors with the purpose of reducing environmental impact (e.g. Froehlich et al. 2010).

Interaction with Other Artifacts and Environment: Deliberation

This level of interaction happens between artifacts and artificial agents and their environment. The lamp is connected to other artifacts which can collect data concerning the means of transportation – for instance, the distance traveled in km, fuel consumption, the quantity of CO_2 emissions etc. – and send it to the lamp. The mobile application is able to recognize the means of transportation – i.e. it is able to recognize if the user is taking the bus, cycling or walking – amongst other data that it collects.

At this level of interaction, which happens between artifacts (e.g. a car key, a bicycle, smartphone, a public transportation payment card etc.) and the environment, the lamp performs a slow and careful kind of reasoning, helping to form an opinion and make a decision. This interaction between artifacts and the material environment enables the construction and modification of an agent's internal concepts, beliefs and goals. It is related to the internal structure of artifacts, thus is hidden from the user but is visible to other agents and artifacts (Fortino and Guerrini and Russo 2012; Ortin and Cueva 2003; Gero and Kannengiesser 2003).

As the intention for designing tools for reflection is to support people in their thinking and reflection, so the relationship that it forms with the user has some similarities to those of ***augment me***, ***engage me***, but is in contrast with ***comply with me***. The ***make me think*** relationship is an equal, balanced one, similar to the relationship between the user and the artifact in the ***augment me*** relationship – e.g. a calculator. In these relationships, the user collaborates with the artifact in order to carry out the task – i.e. reflection: thinking about an activity. The ***make me think*** relationship is similar to the ***engage me*** relationship, because the artifact engages and motivates the user, which is required for achieving a goal. The artifact is used also to encourage the user to think about, but not carry out, the task. So, the characteristics of ***make me think*** relationship show a mix of some features in ***augment me*** and ***engage me*** relationships. Whereas it is in contrast with ***comply with me***, because it is designed to change user's behavior, not to comply with them. Furthermore, ***make me think*** relationship differs from ***augment me*** since its purpose is not to augment user's abilities to carry out tasks, solving problems faster and in a more efficient way. It differs also from ***engage me*** relationship, since user might have not only a personal goal for using personal data, but also other goals that will be decided and defined later in time by user – e.g. reducing the negative impacts on environment by using more bicycle.

We believe this mixed characteristic of ***make me think*** relationship is a fundamental driver that might make tools for reflection part of a distinct category of interactive and smart artifacts (Figure 7). This certainly requires the building of a long-term, constant and enduring relationship between the user and the artifact. In order to build such a relationship, tools for reflection need to create thoughtful interactions with the user, instead of merely displaying information.

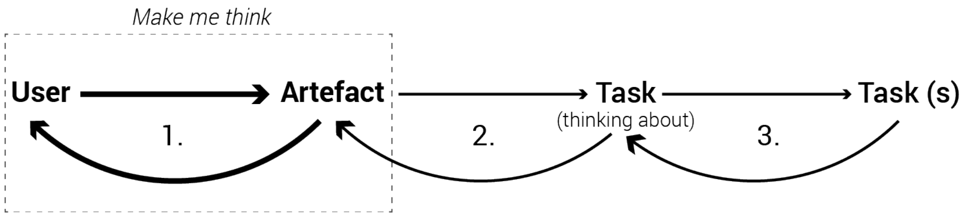

Figure 7: *Make me think* relationship model.

As an attempt to categorize a new kind of relationship with tools for reflection – which are computing artifacts that support reflection in their user – we can summarize the most important characteristics of the ***make me think*** relationship thus: 1) a balanced relationship and collaboration between the user and the artifact; 2) there is a very specific activity that has to be undertaken in relation to the artifact, that is reflective thinking – i.e. which should be related to another activity that needs reflection such as activities related to urban mobility behaviors; 3) the user always has overall control of this relationship; 4) the artifact in this relationship is used to encourage the user to think about, but not carry out, the task – e.g. driving, cycling.

The mobile app senses and collects data related to the user's mobility/transportation activities – walking, cycling and driving – then the lamp lights up in particular ways according to the data received from the mobile app. The behavior of the lamp is the outcome of a system of relationships with other components that are connected to each other.

Discussion

Reflection as A Reference Task

Reflection as a way of thinking is not just an individual and internal process, but requires external stimuli: objects, other people, activities and the environment are all important in the process (Salomon 1993; Rogers 1997). Reflection needs continuity while helping people to acquire a deeper understanding of a situation and then take careful and informed courses of action for change (Sengers et al. 2005; Schön 1983; Dewey 1933). Reflective reasoning is a deep, slow and effortful process (Norman 1993, pp 25). It requires moments of quiet, but also the aid of external support, such as writing, using computing tools, reading books etc. Unlike experiential thinking, reflective thinking is not autonomous or reactive, but rather is about concepts, reconsideration, planning and decision-making. It is not about the elaboration of the information structure that already exists in our brain (Norman 1993).

Reflection can be considered as a user activity or a reference task (Whittaker, Terveen and Nardi 2000) that a computing artifact or a tool for reflection can support. However, a tool for reflection differs from other artifacts that support a user's activities, in some fundamental aspects: 1) the user does not necessarily undertake their daily activity using such artifacts – e.g. they do not drive or cycle using a lamp – rather the presence of the artifact supports reflection about other activities, the experiences and memories associated with it, so reflection can be considered as a process of thinking about an activity; 2) the user thinks about an activity *with* the tool for reflection rather than *through* it – i.e. it does not function as an object in the hand of its user, but rather as a partner. Accordingly, the reference task becomes a relational task that relates to the object (maybe over long periods) rather than serving merely as a tool for solving a particular task.

Reflection is, as such, not a task or a user's problem to be solved, but rather an ongoing activity that should be continuously supported. This is definitely a challenge for interaction designers – how to design tools for supporting a continuous activity (i.e. reflection), rather than designing for activities that can be essentially and efficiently solved as problems, which is the typical model behind the design of computational tools.

Implications for Design Theory and Research

In reflecting upon our own design process as it unfolded during this project, we have also identified a number of implications for the development of design theory, and implications for carrying out this type of research through design. First, a typical design project starts with a design problem or a design brief. However, reflection is not a problem to be solved, and we already think with objects (Turkle 2011). So, instead of tackling the project from one such perspective, we needed to design our project as a process that would encompass reflection as an activity being empowered with computational tools. At the same time, we know that any tool changes the activity it supports, no matter whether the tool is a hammer or a smart object. Accordingly, we not only had to maintain a focus on reflection as an activity undertaken with this object, but also had to keep revising our ideas about what reflection is on a more theoretical level, as we moved forward in this project. The more general lesson to be learnt from this is that it is not only design that redefines tasks, or resolves problems (on a practical level), but also design projects that challenge and change the ideas guiding the design. Therefore, design concepts should not be seen as a starting point for a design project, nor be seen as a stable construct throughout a project, but rather as a theoretical factor that also changes as the project moves from early drafts to the final design. Design theory (and to theorize design) is not separable from the design process, just as our everyday objects that we think with cannot be separated from the activity of reflection.

If our theoretical notions change over the course of a design project, then that also has implications for the research design. This project, with a focus on designing for reflection, has identified this fact, and has illustrated how the design research not only needs to be iterative in terms of alternating between theories on reflection and practical design work in designing for reflection, but how each step of the research process needs to bridge between the design concepts that guide the design process, and the designed artifacts that illustrate the ideas in material and computational form.

Implication for Designing IoT Systems

There are a number of additional lessons to be learnt from this project, not only in terms of designing for reflection, or how this project in itself has been a reflective process where we have alternated between ideas about reflection and how those ideas can be manifested and expressed in the design. There are also lessons to be learnt and implications to be derived for the design of IoT systems in general. First, the design of IoT systems is about the design of a system of objects where 1) the connectivity between the objects is a central assumption, and 2) where "objects" are clearly distinguishable from each other. As a consequence, any design approach to the IoT is simultaneously about bringing pieces (or objects) together, and about keeping things (objects) apart. While this is a general concern for any IoT project, it becomes very clear when designing IoT systems for reflection. As "thinking with objects" is such an inseparable activity, it becomes hard to separate the "object to think with" from the person who has a reflective relationship with the object. On the other hand, the notion of "smart objects" has brought with it a conceptualization of computational power in material form. A smart object is typically something computational, but also physical. Accordingly, and from that perspective, "smart objects to think with" manifest this general design challenge of simultaneously designing standalone entities while also designing these entities to work in concert – as a system.

Conclusion

In this paper, we described four models of IoT systems which have four different simple relationships with a few essential components, but all of which can be scaled up to include more users, artifacts and environments (Brown, Bødker and Höök 2017). From a systems perspective, this modeling technique: 1) highlights that the environment created by objects is about the relationship between artifacts; 2) shows the evolution of technical systems that enable building such IoT systems and 3) gives a systemic understanding of the object and its user, and how such relationships enable people to undertake new tasks, think differently and solve complex problems. There are emergent aspects of the system, such as the relationship that the user makes with the artifact. So, from this perspective, it is the emergent aspect, not the artifact itself, that is of central concern.

We are moving towards the development of smarter computing artifacts, artificial intelligence for the so-called Internet of Things (IoT). The IoT has been defined as a network of computing artifacts, people and environments, which are connected and communicate with each other through Internet connectivity. They can sense, collect and exchange data, and provide feedback. Our environments are increasingly filled with such networks – e.g. Google home, Nest thermostat, Alexa, etc. – and we constantly interact with them in our daily lives. These systems of things are, to a large extent, about relationships between people, objects, places and activities. Therefore, it seems reasonable that, being actually surrounded by such networks and related to them, we should try to understand our relationships with them. In order to understand the ways in which we create a relationship with such systems, we proposed simple models with few components. We suggested also a relational approach in order to help us to understand and design such IoT artifacts and systems that support different types of user activities. This relational approach can not only offer a better understanding of the existing IoT artifacts/systems and their internal relationships between the user, user activity and the situation, but can also support the design of new IoT artifacts/systems. This is particularly relevant for designing computing artifacts in a system that aims to support reflection where reflection is seen as an activity which is relational in nature, as described by the distributed cognition theory.

This modeling approach helped with an analysis of three examples of existing relationships with computing artifacts, namely: ***augment me***, ***comply with me*** and ***engage me***. We sought to explain the characteristics and the components of these relationships using examples. Then, as another example, we focused on the ways computing artifacts can support reflection of a user. After providing a brief study of literature on reflection, related works in HCI and cognitive technologies, we presented some properties of such artifacts using a prototype lamp. Building upon its characteristics, which were engaging, transformative, communicative and deliberative, we created the model of the ***make me think*** relationship.

In addition, in this paper, we have identified the fundamental components of an IoT system as being: 1) the user; 2) computing artifact; 3) user's activity or task, and 4) situation – which is the context within which the activity occurs and also other computing artifacts connected to the system. Then we have discussed about 1) reflective thinking as an activity, which is of increasing interest and importance to the HCI and design communities, 2) our methodology and how it can contribute to on-going design research methodologies, 3) the implications for designing IoT system.

We believe the analysis of the relationships in an IoT system becomes even more relevant as we increasingly 1) consider the design of ecologies and systems of smart artifacts, and 2) consider reflection as a concept in design outcomes, especially in the design of smart and interactive artifacts (Ghajargar and Wiberg 2018).

We conclude our paper by providing some suggestions for future research: 1) designing artifacts for the Internet of Things is actually about designing a system which is, to a large extent, about the relationships between its components, and how we define and understand these relationships is crucial for designing future IoT systems; 2) the user activity in this system can define the relationships between the user, computing artifact and situation; 3) in systems designed to support reflective thinking, the sensory and physical characteristics of the artifact itself play crucial roles – e.g. its behaviors and affordances, and 4) reflective thinking can be considered as a reference task in HCI itself, but is distinguished from other tasks because it is related to another user activity.

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References

1. Aipperspach R., Hooker B., Woodruff A. (2010). Data Souvenirs: Environmental psychology and reflective design. *International Journal of Human-Computer Studies* 69(5), 338-349.

2. Allen P. V. (2007). *The New Ecology of Things*. Media Design Program at Art Center College of Design; Limited edition.

3. Ashton, K., (2009). That 'Internet of Things' Thing, in the real-world things matter more than ideas. *RFID Journal*. Retrieved January 2018, http://www.rfidjournal.com/articles/view?4986.

4. Bakker S., Hoven E., Eggen (2015). Peripheral interaction: characteristics and considerations. *Personal and Ubiquitous Computing* 19(1): 239-254.

5. Banathy, B. A. (1996), Information-based design of social systems. *Systems Research* 41: 104–123.

6. Baumer, E. P. S., Khovanskaya, V., Matthews, M., Reynolds, L., Schwanda Sosik, V., & Gay, G. (2014). Reviewing Reflection: On the Use of Reflection in Interactive System Design. *Proceedings of the 2014 Conference on Designing Interactive Systems*. 93–102: ACM.

7. Beaumie, K., Reeves, T. C. (2007). Reframing research on learning with technology: in

search of the meaning of cognitive tools, *Instructional Science*, 35(3) 207-256.

8. Bertalanffy, L. (1968). *General system theory: Foundations, development, applications.* New York: G. Braziller.

9. Bødker S. (1989). A human activity approach to user interface. *Journal of Human-Computer Interaction* 4 (3), 171-195.

10. Bowen S., Petrelli D. (2010) Remembering today tomorrow: Exploring the human-centred design of digital mementos. *International Journal of Human-Computer Studies* 69 (5), 324-337.

11. Brown B., Bødker S., Höök K. (2017) Does HCI scale?: scale hacking and the relevance of HCI. *interactions* 24 (5), 28-33.

12. Braber M. D. (2016), The emergence of Quantified Self as a Data-driven Movement to Promote Health and Wellness. *Proceedings of the first workshop on lifelogging tools and applications* pp. 1-1: ACM.

13. Churchman, C. W. (1968). *The Systems Approach*. New York: Delacorte Press.
14. Crilly N. (2010). The roles that artifacts play: technical, social and aesthetic functions. *Design Studies*, 31(4) 311-344.

15. Crilly, N., Good, D., Matravers, D., Clarkson, P. J. (2008). Design as communication: exploring the validity and utility of relating intention to interpretation. *Design Studies* 29(5), 425 – 457.

16. Dewey, J. (1910). *How we think*. Boston: D. C. Health and Company.

17. Dewey, J. (1933) *How We Think. A restatement of the relation of reflective thinking to the educative process*. Boston: D. C. Heath and Company.

18. Dietrich M., Van Laerhoven K. (2014). Recall your Actions! Using Wearable Activity Recognition to Augment the Human Mind. *Proceeding of Ubicomp '14 Adjunct,* pp. 1347-1353.

19. Dietrich M., Van Laerhoven K. (2016). An Interdisciplinary Approach on the Mediating Character of Technologies for Recognizing Human Activity. *Philosophies*, 1(1), 55-67.

20. Dix A. (2009). Human-computer Interaction. In L. Liu, M. T. Özsu (Eds.) *Encyclopedia of database systems* (pp 1327-1331): Springer, US.

21. Dourish P. (2004), *Where the Action is*. Cambridge: MIT Press.

22. Fleck R. (2012). Designing for Reflection, Sustainability and Simplicity, Presented at: Workshop on Simple, Sustainable living, *CHI'12*, Austin, Texas.

23. Fleck R., Fitzpatrick G. (2010). Reflecting on Reflection: Framing Design Landscape. In *Proceedings of the 22nd Conference of the Computer-Human Interaction, Special Interest Group of Australia on Computer-Human Interaction*, pp. 216-223. ACM.
24. Fortino G., Guerrini A., Russo W. (2012). Agent-oriented Smart Artifacts development.

Proceeding of the 16th International conference on Computer Supported Cooperative Work in Design, pp. 907-912. ACM.

25. Froehlich J., Findlater L., Landay J. (2010). The design of eco-feedback technology. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'10)*, pp. 1999-2008. ACM.

26. Gašević D., Mirriahi N., Dawson S. (2014). Analytics of the effects of video use and instruction to support reflective learning. *Proceedings of the 4th International Conference on Learning and Analytics and Knowledge (LAK'14)*, pp. 123-132. ACM.

27. Ghajargar M., De Marco A., Montagna F. (2017). "Wise Things": When smart objects stimulate reflection. *Proceeding of 11th International Conference on Interfaces and Human Computer Interaction (IHCI),* pp. 233-238, IADIS press.

28. Gero, J., Kannengiesser, U. (2003). Function-Behavior-Structure: A model for social situated agents. Workshop on Cognitive Modeling of Agents and Multi-Agent Interactions, *Proceeding of International Joint Conference on Artificial Intelligence*. pp. 101, 107.

29. Ghajargar, M., Giannantonio, R., Ghajargar, M. (2015). Towards Environmental Inclusion: Fostering inclusive mobility behaviours through Internet of Things. *Proceeding of INCLUDE 2015*, p. 5.

30. Ghajargar M., Wiberg M. (forthcoming - 2018). Thinking with Interactive Artifacts: Reflection as a Concept for Design Outcomes. *Design Issues*. 34(2), Spring 2018. MIT press.

31. Hallnäs L., Redström J. (2001). Slow Technology, Designing for Reflection. *Personal and Ubiquitous Computing*, 5(3), 201-212.

32. Hornecker, E., Buur, J. (2006). Getting a grip on tangible interaction: a framework on physical space and social interaction. *Proceedings of the SIGCHI conference on Human Factors in computing systems*, pp. 437-446. ACM.

33. Houben S., Golsteijn C., Gallacher S., Johnson R., Bakker S., Marquardt N., Capra L., Rogers Y. (2016). Physikit: Data Engagement Through Physical Ambient Visualizations in the Home. *Proceeding of the CHI' 16, the SIGCHI conference on Human Factors in computing systems,* pp. 1608-1619.

34. Hutchins, E. (1995). *Cognition in the wild*. Cambridge, MA: MIT press.

35. Ishii, H., Ullmer, B. (1997). Tangible bits: towards seamless interfaces between people, bits and atoms. *Proceedings of the SIGCHI conference on Human factors in computing systems,* pp. 22-27. ACM.

36. Isaacs, E., Konrad, A. Walendowski, A. Lennig, T. Hollis, V., Whittaker, S. (2013). Echoes From the Past: How Technology Mediated Reflection Improves Well-Being. Conference on Human Factors in Computing Systems - Proceedings (CHI'13), 1071-1080: ACM.

37. Janlert L-E, Stolterman E. (1997). The character of things. *Design Studies* 18(3), 297-314.
38. Janlert L-E., Stolterman E. (2014). Faceless Interaction–A conceptual Examination of the

Notion of Interface: Past, Present, and Future. *Human-Computer Interaction*, 30(6), 507-539.

39. Janlert, L-E., Stolterman, E. (2017). The meaning of interactivity—some proposals for definitions and measures. *Human–Computer Interaction*, 32 (3), 103-138.

40. Janlert, L.-E., and E. Stolterman. 2017. *The Things That Keep Us Busy: The Elements of Interaction.* Cambridge, MA: MIT Press.

41. Jenkins T. (2015). Designing the "Things" of IoT. *Proceedings of the 9th International Conference on Tangible, Embedded and Embodied Interaction (TEI' 15),* pp. 449-452. ACM.

42. Jonassen, D. H. (1997). Instructional Design Models for Well-Structured and Ill-Structured Problem-Solving Learning Outcomes. *Educational Technology Research and Development.* 45 (1), 65–94.

43. Jonassen, D. H., & Reeves, T. C. (1996). Learning with technology: Using computers as cognitive tools. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology,* 1st edition. (pp. 693-719). New York: Macmillan.

44. Kalnikaite V., Whittaker S. (2011) A saunter down memory lane: digital reflection on personal mementos. *International Journal of Human-Computer Studies* 69 (5), 298-310.

45. Kaptelinin V., Nardi B. A. (2006). *Acting with technology, activity theory and interaction design.* MIT Press.

46. Kefalidou G., Skatova A., Brown M., Shipp V., Pinchin J., Kelly P., Dix A., Sun X., (2014) Enhancing self-reflection with wearable sensors. *Proceedings of the 16th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct* pp. 577-580. ACM.

47. Kolko, J. (2011). *Thoughts on interaction design*. Elsevier (second Ed.).

48. Kortuem, G., Kowsar, F., Fitton, D., Vasughi, S., (2010). Smart artifacts as building blocks for the Internet of things, *Journal of Internet Computing, IEEE*, 14(1), 44 – 51.

49. Lajoie, S. P., & Derry, S. J. (Eds.). (1993). *Computers as cognitive tools*. Hillsdale, NJ: Lawrence Erlbaum.

50. Laschke, M., Diefenbach, S., & Hassenzahl, M (2015). Annoying, but in a nice way: An inquiry into the experience of frictional feedback. *International Journal of Design*, 9(2), 129-140.

51. Li, I., Dey, A., Forlizzi, J. (2011). Understanding My Data, Myself: Supporting Self-Reflection with Ubicomp Technologies. *Proceedings of the 13th international conference on Ubiquitous computing*, pp. 405-414.

52. Lim Y., Stolterman E., Tenenberg J. (2008). The anatomy of prototypes: Prototypes as filters, prototypes as manifestations of design ideas. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 12 (2), ACM.

53. Malafouris, L. (2008). At the Potter's Wheel: An Argument for Material Agency. In *The Material Agency* Lambros Malafouris and Lambros Knappett (eds.). Springer US, 19-36.

54. McKinnon H. (2016). Domestic Reflections, Electric Reflections: Design Interventions Foregrounding Energy Mundanity in the Home. *Design Issues* 32(4), 29-39: MIT press.

55. Norman, D., (1993). *Things that make us smart: defending human attributes in the age of the machine*. Boston, MA: Addison-Wesley Longman Publishing Co., Inc.

56. Norman, D. (2007). *The Design of Future Things*, New York: Basic Books.

57. Norman, D. (1988). *The design of Everyday Things*, 1988. New York: Basic Books.

58. Ortin, F., Cueva, J. M. (2003). Non-restrictive computational reflection. *Journal of Computer Standards & Interfaces*. 25(3), 241-251.

59. Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. New York: Basic Books.

60. Pea, R. (1985). Beyond amplification: using the computer to reorganize mental functioning. *Educational Psychologist*, 20(4), 176–182.

61. Pea, R.D. (1993). Practices of distributed intelligence and designs for education. In G. Salomon (Ed.), *Distributed cognitions: Psychological and educational considerations* (pp. 47-87). New York: Cambridge University Press.

62. Perkins, D.N. (1993). Person-plus: A distributed view of thinking and learning. In G. Salomon (Ed.), *Distributed cognitions. Psychological and educational considerations* (pp. 88-110). New York: Cambridge University Press.

63. Piaget, J. (1947). *The Psychology of Intelligence*. New York: Routledge.

64. Ploderer B., Reitberger W., Oinas-Kukkonen H., Gemert-Pijnen J., (2014). Social Interaction and reflection for behavior change, *Personal and Ubiquitous Computing* 18(7), 1667-1676.

65. Pousman Z., Stasko J. (2006). A taxonomy of ambient information systems: four patterns of design. *Proceedings of the working conference on Advanced visual interfaces*, pp. 67-74.

66. Preece, J., Rogers, Y. and Sharp, H., (2002). *Interaction design: beyond human-computer interaction*. New York: John Wiley & Sons.

67. Price, S., Rogers, Y., Scaife, M., Stanton, D., Neale, H., (2003). Using 'tangibles' to promote novel forms of playful learning. *Interacting with computers* 15(2), 169-185.

68. Purta R., Mattingly S., Song L., Lizardo O., Hachen D., Poellabauer, Striegel A. (2016). Experiences measuring sleep and physical activity pattern across a large college cohort with fitbits. *Proceedings of the International Symposium on Wearable Computers (ISWC'16)*, pp. 28-35. ACM.

69. Robbins H., Giaccardi E., Karana E. (2016). Traces as an Approach to Design for Focal

Things and Practices. Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI'16), pp. 1-10. ACM.

70. Rodgers C., (2002), Defining Reflection: Another Look at John Dewey and Reflective Thinking, *Teachers College Record*, 104(4), 842-866.

71. Rogers Y. 1997. A Brief Introduction to Distributed Cognition. Retrieved March 12, 2017 from: http://mcs.open.ac.uk/yr258/papers/dcog/dcog-brief-intro.pdf

72. Rogers, Y., Muller, H. (2006). A framework for designing sensor-based interactions to promote exploration and reflection in play. *International Journal of Human-Computer Studies.* 64(1), 1-14.

73. Salomon, G. (1993). *Distributed cognitions: Psychological and educational considerations*. New York: Cambridge University Press.

74. Sas, C., Dix, A. (2009). Designing for reflection on personal experience. *Proceedings of CHI '09 Extended Abstracts on Human Factors in Computing Systems*, 4741-4744.

75. Sas, C., Dix, A. (2011). Designing for reflection on personal experience. *International Journal of Human-Computer Studies*. 69 (5), 281-282.

76. Schön D. (1983). *The reflective practitioner: how professionals think in action*. New York: Basic Books.

77. Sengers P., Boehner K., David S., Kaye J., (2005). Reflective design. *Proceedings of the 4th Decennial Conference on Critical Computing: Between Sense and Sensibility*, 2005, Aarhus, Denmark.

78. Shackel, B. (1984). The concept of usability. In: J. Bennet, et al., (Eds) *Visual display terminals.* Englewood Cliffs, NJ: Prentice-Hall, Inc., 45–88.

79. Shannon, C. E. (1948). A Mathematical Theory of Communication, *The Bell System Technical Journal* 27, 379–423, 623–656.

80. Sheryl Turkle, (2011), *Evocative Objects: Things we Think with.* MIT Press.

81. Schultz P. W., Shriver C., Tabanico J. J., Khazian A. M. (2004). Implicit connections with nature. *Journal of Environmental Psychology* 24(1), 31-42.

82. Taylor A. (2015). After interaction. *interactions* 22(5), 48-53.

83. Thieme A., Wallace J., Thomas J., Chen K., Krämer N., Olivier P. (2010) Lovers' box: Designing for reflection within romantic relationships. *International Journal of Human-Computer Studies* 69(5), 283-297.

84. Valkanova N., Jorda S., Tomitsch M., Moere A. V. (2013) Reveal-it!: the impact of a social visualization projection on public awareness and discourse. *Proceedings of CHI'13*, pp. 3461-3470: ACM.

85. Vardouli, T., (2015). Making use: Attitudes to human-artifact engagements, *Design Studies*

41, part A, 137-161.

86. Verplank, B. (2009) Interaction Design Sketchbook: Frameworks for designing interactive products and systems. https://ccrma.stanford.edu/courses/250a-fall-2004/IDSketchbok.pdf. Last access July 2 2016.

87. Weiser, M. (1991). The Computer for the 21st Century. *Scientific American* 26(3): 94–101.

88. Weiser, M. and Brown, J.S., (1995). Designing Calm Technology. http://www.ubiq.com/hypertext/weiser/- calmtech/calmtech.htm.

89. Whittaker S., Terveen L., Nardi B., (2000). Let's Stop Pushing the Envelope and Start Addressing It: A Reference Task Agenda for HCI. *Human-Computer Interaction,* 15(2), 75-106.

90. Wiberg, M. (2012) Landscapes, Long tails & Digital Materialities – Implications for Mobile HCI research, *International Journal of Mobile Human Computer Interaction*, 4(1), pp 18.
91. Wiberg, M. & Zaslavsky, A. (2010) Landscaping Future Interaction: Special Issue on Mobile and Ubiquitous Multimedia, Guest Editors Introduction, *IEEE Multimedia*.

92. Wiberg, M. (2018) *The materiality of interaction: notes on the materials of interaction design*. MIT press.

93. Young A. L. (2015), The role of accidental Self-Reflection in wearable camera research. *Proceedings of the 17th International Conference on Human-Computer Interaction with Mobile Devices and Services Adjunct (MobileHCI'15),* pp. 1062-1065. ACM.

94. Zuboff S. (1984). *In the age of the smart machine: the future of work and power.* Basic books: New York.

[i] As the operations of installing and adjusting are often necessary in order to run and use any kind of computing artifacts, so have not been considered in models as components.

[ii] This is part of a project in collaboration with Telecom Italia Mobile Open Innovation Center.